WESTERN UNION Technical Review

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Soldered Connections In Electrical Circuits

A CONNECTION is, broadly, two or more parts of an electrical circuit which are fastened together to complete the circuit. To keep such a connection normally continuous and low in electrical resistance and at the same time permit it to be opened at points for testing, repair or replacement, is a problem of major importance. Electrical connections were all originally of the solderless type, the screw connection being the most common. Difficulties with this type of connection, namely, looseness and increasing resistance, led to the general use of soldered connections for electrical purposes. Difficulties with soldered connections of the kind covered by this article led to a resumption of the use of solderless connections. These include, in addition to the screw type, the crimped, the pressure crimped, the clinched and, more recently, the wrapped type. All solderless connections have one basic design detail in common which is elastic stress in the mating members. All such connections that rely on built-in mechanical stresses have the common fault that those stresses will relax with time.

This paper is primarily concerned with the soldering of electrical connections. Most connections today are soldered because soldering is, first, economical and effective; second, permanent electrically and mechanically *if correctly made initially;* and third, susceptible of quick disconnection and easy reconnection.

Electrical connections are indispensable to all types of electrical circuits, apparatus and equipment. They are important in manufacture, installation, operation and maintenance. There are few companies, however, whose interest extends to all these phases; most manufacturers are *primarily* interested in initial performance, other organizations are interested in the installation phase, and still others are interested chiefly in the operation and maintenance phases. Western Union and the Bell System, however, are directly and continuously concerned with all phases of design, development, manufacture, installation, operation and maintenance of their apparatus, equipment and instruments, from their initial development through their use, replacement and ultimate junking. A defect in one part of a unit affects a second or third unit and will continue to do so in one form or another until its final correction.

A circuit is usually defined in part as the "complete path of an electric current." Would anyone permit variable resistors, which bear no relation to the normal functioning of a circuit, to be introduced between the circuit components without the knowledge of the designer? *This is exactly what is happening in varying degrees when soldered connections are made with fluxes that are conductive to a greater or less extent.* If one would have a circuit function as designed, there is only one way it can be accomplished with certainty, and that is to solder all electrical connections using rosin as the flux. All substitute and proprietary fluxes, as will be shown, conduct electric currents in varying degrees.

Solder Properties

Research on solders, fluxes, and so forth, done by Western Union in 1942, was the principal basis for the War Production Board's order on solders during World War II. These data on the solders and methods developed were also given to some of the largest communication, power and utility companies for their war use as a patriotic service. Our research was so basically correct that the company never returned to either the prewar solders or methods.

Solders are, in general, alloys of tin and lead and as such do not have "melting points" with the single exception of the eutectic alloy. A proper understanding of the action of solders of different composi-

tions, even though only one alloy is used, will help much in simplifying the problem of soldered connections.

Solder has a "solidus point temperature" and a "liquidus point temperature." The solidus point temperature is that temperature above which the metal changes from the solid state to a consistency neither solid nor liquid, known as a "pasty" state. Figure 1 is the equilibrium diagram of solders and shows the different physical states of the various tin-lead alloys as they change with temperature. Only one, the eutectic alloy, has a melting point. This alloy, 62-percent tin, 38-percent lead, as shown in Figure 1 changes from the solid state to the liquid state at one temperature, namely, 361 degrees F.

Many books and published data, however, give the "liquidus" point temperatures as the "melting points" of the different alloys, which is confusing. Reference to Figure 1 shows the trouble which may result. For example, 35-percent tin solder changes from the solid state to the pasty state at 361 degrees F and remains in the pasty state from 361 to 477 degrees F. At and above the latter temperature it remains in the completely liquid state. In cooling, the same solder passes through these states in the reverse order. At 477 degrees F it changes to a pasty state and remains in that state until 361 degrees F solidus temperature is reached.

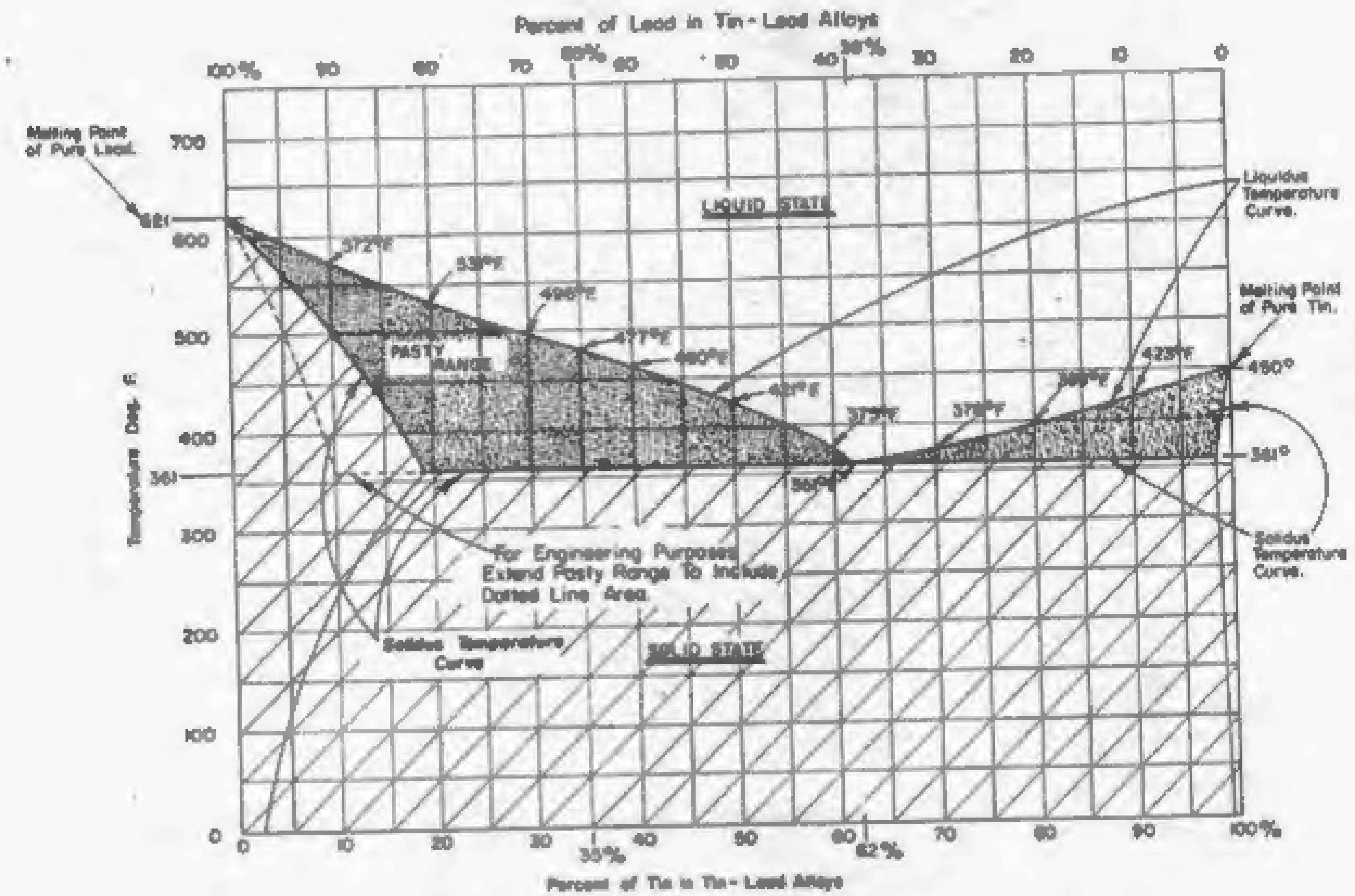


Figure 1. Melting and freezing ranges of tin-lead alloys

Reference to Figure 1 also readily shows that if difficulty is experienced with solder not solidifying fast enough or with soldered connections opening or becoming defective in a cabinet heated by resistors, tubes, and so forth, to a temperature approximating 475 degrees F, no advantage would be obtained in changing from a 35-percent tin solder to a 20-percent tin solder. Even though the liquidus temperature of 20-percent tin solder is 531 degrees F, the solidus temperature of both solders is still 361 degrees F. Thus, the 20-percent solder would be in the pasty state at the same temperature as the 35-percent solder.

To select a 50-percent tin solder would effect no improvement since the solidus temperature of 50-percent tin solder is also 361 degrees F.

Along with the explanation of the quantity or amount of heat required per pound of the solder metal, it will be found that increasing the tin content does not improve production but, to the contrary, tends to hinder it, since it requires more time to absorb or to dissipate a larger quantity of heat from a high tin-content solder than from a low tin-content solder.

quires a total of 39 BTU per pound to bring it up to 100 degrees F above the liquidus temperature while an 80-percent tin alloy requires a total of approximately 56 BTU to raise this tin-rich solder to 100 degrees F above its liquidus temperature. Now, to the contrary, it will be noted that the 20-percent tin alloy has a relatively high liquidus temperature (531 degrees F), while the 80-percent tin alloy has a lower liquidus temperature (399 degrees F). However, reference to Figure 1 shows that both solders change from the solid

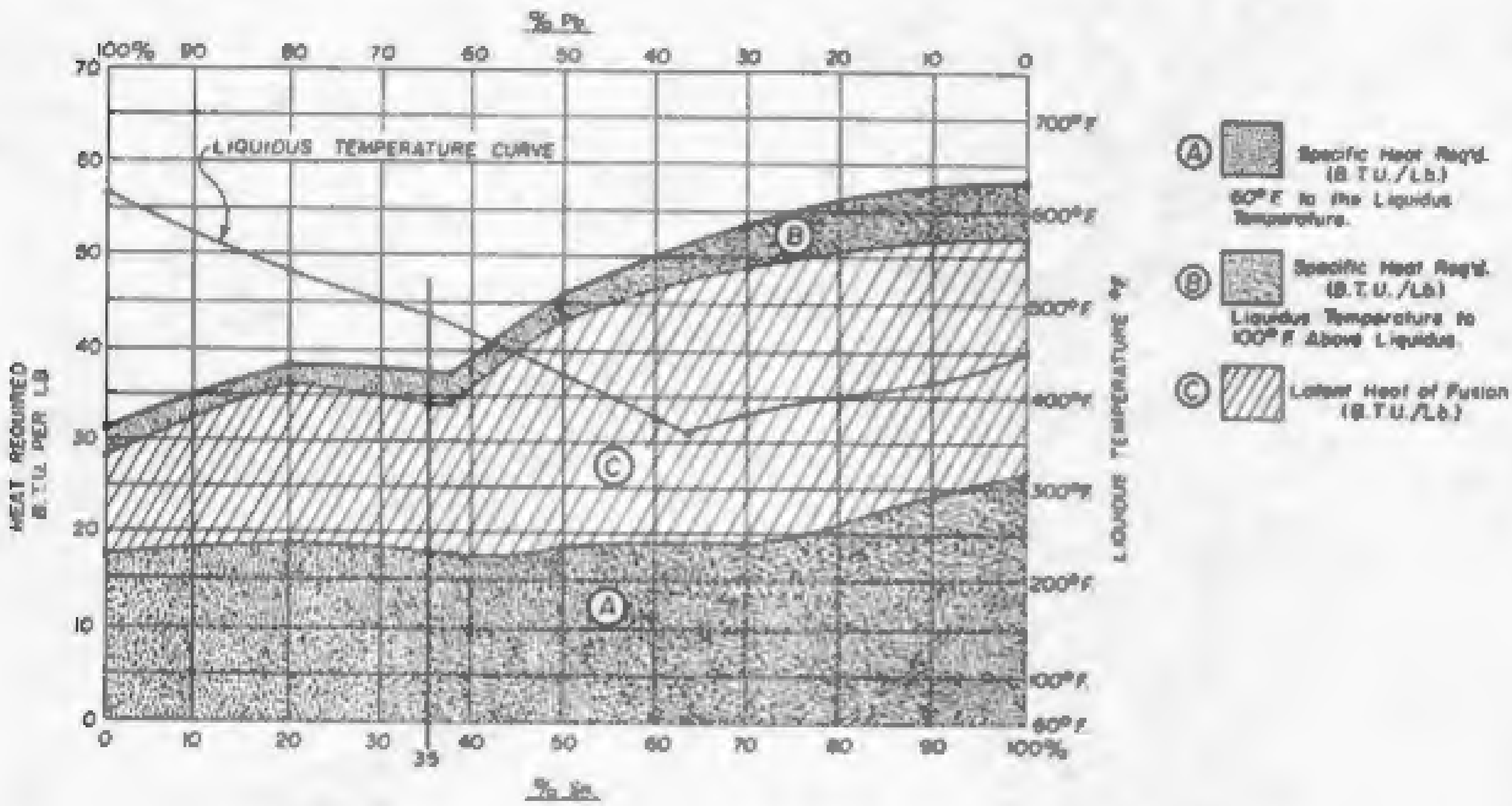


Figure 2. Heat required versus tin content; heat required versus liquidus temperature

Figure 2 illustrates the relation of the quantity of heat required per pound of solder with respect to its tin content, and the relation of the required heat to the liquidus temperatures of the different solders.

In (A) Figure 2 is shown the amount of specific heat required to raise the solder from normal atmospheric temperature (60 degrees F) to the liquidus temperature. In the same figure, the amount of specific heat from liquidus temperature to 100 degrees F above liquidus is shown as (B).

It should be noted that there is little relation of the property of one solder alloy to the same property of another alloy. Thus, a 20-percent tin alloy solder re-

state to the pasty state, and vice versa, at the same solidus temperature, 361 degrees F.

This solidus point for all solders should be understood for several reasons. First, it is the point where any movement of the soldered connection in the cooling cycle will seriously affect the soldered part of the connection. Movement of the connection above or below this point, as previously explained, will not appreciably affect it. The second reason for understanding the changes which take place at the "solidus" point is that at this temperature an important thermal effect also occurs. At this temperature a quantity of latent heat of fusion must be added to the

metal in order to change the solder from the solid state to the pasty state *but with no change in temperature*. This latent heat of fusion is shown as (C) in Figure 2.

The sum of the quantity of heat shown as (A), (B) and (C) indicates the total heat required in BTU/lb. of solder to heat any solder alloy shown by Figure 2 from 60 to 100 degrees F above its liquidus temperature.

quantity of latent heat must be dissipated at the only point where movement is critical to the soldered connection.

If the solder is moved at this juncture of the cooling cycle, it will have the appearance of a dull silver finish and even though the temperature may have been high enough or even too high for good soldering, this fault will be usually listed as due to either cold solder or inadequate

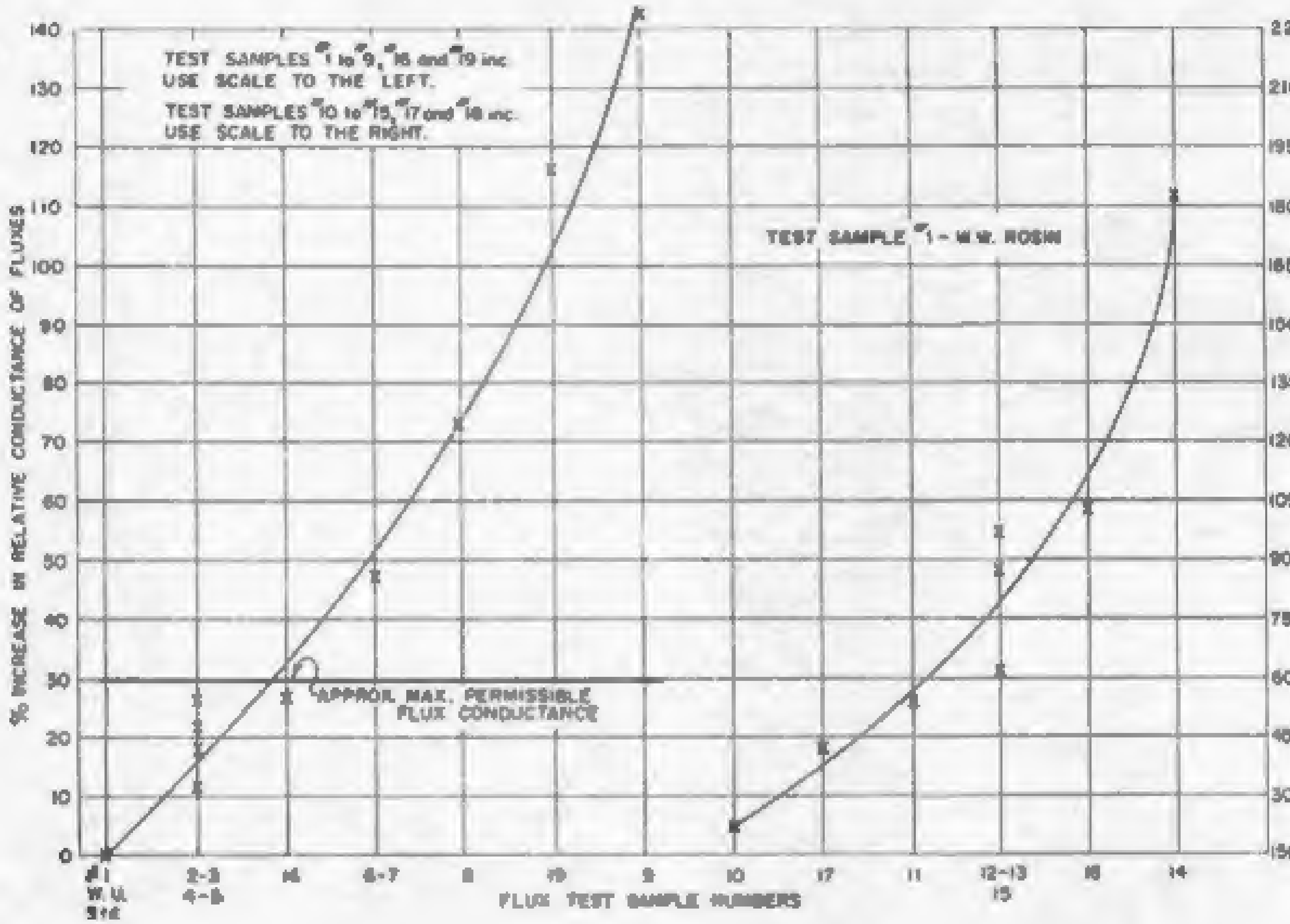


Figure 3. Percent increase in relative conductance of fluxes compared to W. W. rosin

All of the specific and latent heat of fusion is supplied by the soldering iron in the heating cycle and is not generally noticeable, particularly in the soldering of small connections. On the other hand, the critical point comes in the cooling cycle, since a uniform quantity of specific heat is dissipated with each degree change in temperature; whereas the total quantity of latent heat of fusion must be dissipated or lost at the solidus temperature *but with no change in temperature*. Thus, the cooling is actually retarded at the solidus point since, in addition to losing the specific heat per degree F, this relatively large

flux. Actually, it is largely due to heating the parts at too high a temperature which results in an increase in the cooling time required, thus misleading one into believing that the solder must have cooled to a point below the solidus temperature. This failure again demonstrates that too high soldering temperatures require unnecessarily long cooling periods which may produce defective connections and, in general, increase the cost of production.

Again, if it is assumed that the "cold" solder may have been due to the insufficiency of flux, this condition could easily have been caused by too high, not too low,

a soldering temperature since, as previously explained, too high a temperature of application will cause volatilization of the flux constituent of the rosin, thus giving the appearance of either insufficient flux or no flux. This trouble is often blamed on flux voids in the cored solders.

Electrical Conductivity of Solders

The electrical conductivity of solder is very much less than that of copper but in the soldered connection the conductivity of the solder alloy is sufficient to make the connection low in resistance and to maintain it in that condition. Wire connections are usually made with some form of mechanical wrap, twist or clamp that is sufficient initially to give the necessary electrical conductivity to the connection. The soldered portion of the joint gives permanence and strength to the connection and maintains the necessary uniformity in low resistance. The electrical conductivity of the solder, therefore, enters only indirectly into the problem of the electrical connection. The following Table I gives the electrical conductivity of tin-lead solders.

TABLE I

ELECTRICAL CONDUCTIVITY OF SOLDERS

TIN-LEAD ALLOYS

SN %	PB %	CONDUCTIVITY PERCENT OF COPPER	
100	0	13.90	
80	20	13.20	
62	38	11.67	Eutectic
60	40	11.50	
40	60	10.10	
35	65	9.40	W. U. Standard
20	80	8.70	
0	100	7.91	

From the above table it is obvious that electrical connections in general should be designed so that heavy currents are not all directly conducted by the solder. In other connections where no appreciable current is involved, the solder has the necessary conductance to guarantee the maintenance of the connection.

Relative Electrical Conductance of Rosin and Other Fluxes

Perhaps the best way to induce you further to "lend me your ears" is to give you some idea of the electrical conductance of different fluxes when compared to rosin. It is difficult to give absolute values and it is questionable if they would be of much use, but relative values are of more practical worth if some criterion, such as rosin, is employed as a basis of comparison in the tests.

Table II gives the sample numbers and the corresponding general group or type classification of representative commercial fluxes tested. The relative increase in electrical conductance of these fluxes as compared to rosin is shown in Figure 3. The curves in the figure represent the average values of two tests, each employing the same method. A third test by a different method was used to check the other two. The conditions of all tests were the same in order to make all values comparable.

The fact that rosin had the lowest conductivity of any flux available was anticipated but the increase in conductivity due to the addition of any plasticizer, activator or other adulterant is strikingly evident from the curves.

The tests even show that the practice by many manufacturers of adding a plasticizer to the rosin in order to facilitate flux-cored solder manufacture actually increases the electrical conductance of rosin. Samples sold as pure rosin or as containing only a plasticizer are shown as Test Samples Nos. 2, 3, 4 and 5. A plasticizer should not be confused with an activator since the latter is an added active agent intended to aid or replace the fluxing constituent of the rosin.

Sample No. 7 represents a flux-cored solder supplied by one of the larger manufacturers as "rosin flux" but which must have had more than a plasticizer added and illustrates the subtle nature of rosin adulterants. This flux, which on Figure 3 shows an increase in conductance over W. W. rosin (Sample No. 1) of approximately 48 percent, caused sufficient leakage between circuit components at the

soldered connections to cause the complete malfunctioning of special electronic test apparatus in our own laboratory. The apparatus was taken apart and tested piece by piece and the entire trouble definitely localized at the soldered connections and traced to the flux residue. Now if a value of 30 is employed in Figure 3 as the approximate maximum value permissible for the electrical conductance of rosin in sensitive electrical circuits, it will be apparent that so-called activated rosin flux (Nos. 8, 10, 11 and 14) are as dangerous to such circuits as the other chloride or proprietary fluxes tested. Test Samples Nos. 12, 13 and 15 are chloride paste fluxes of a nationally advertised type.

Beyond giving the general identity of the fluxes tested, no effort has been made to name the products, give their trade names or to provide specific values of the tests. Additional tests, not included, show that changing humidity, temperature, material, voltage and other conditions affect the conductance of all the fluxes tested so as to increase the indicated test values appreciably, with the single exception of rosin, which remained fairly constant in all tests.

Relative Corrosiveness of Rosin, Activated Rosin and Proprietary Fluxes

Corrosiveness of a flux seems to have been made its prime consideration when used for electrical purposes, but while corrosion is important, the difficulties experienced with the corrosive effects of a flux are of less importance than its electrical conductance.

Rosin has been known for some time past to be wholly noncorrosive and also to leave a flux residue that is noncorrosive. The tests shown in Table III confirm that general knowledge. This table shows the results of identical tests made on W. W. rosin and on the various substitute fluxes, and provides a relative comparison of the corrosiveness of other types of fluxes.

It should be noted, however, that during more than two-thirds of the test periods, the relative humidities were 50 percent or less which makes them simulate frequently encountered conditions more closely than the 92-percent relative humidity tests.

Table III shows quite definitely that some of the fluxes are more corrosive than others. It also shows that in the case of some fluxes there is a general relation-

TABLE II

SAMPLE NUMBERS AND GENERAL CLASSIFICATION OF FLUXES TESTED

SAMPLE NO.	CLASSIFICATION OF FLUXES BY TYPES
1	Water-white (W. W.) rosin—Laboratory sample conforming to Western Union's specifications
2-3	Rosin removed from commercial types of rosin core solders. Containing little or no plasticizer
4-5	Rosin removed from commercial types of rosin core solders but apparently containing a plasticizer (not an activator)
6-7	Rosin removed from cored solders, both containing mild activators
8	Rosin-stearine flux removed from cored solder
9	Stearine flux removed from cored solder
10-11	Proprietary activated rosin removed from cored solder
12-13-15	Paste and stick types of chloride emulsion fluxes (nationally advertised types)
14	Proprietary flux claimed to be pure rosin but activated by a chemical process. Removed from cored solder (foreign manufacture)
16	Proprietary flux
17	Flux claimed to be as nonconductive and noncorrosive as rosin but as active as an acid flux
18	Proprietary flux, claimed to be equal to rosin (foreign manufacture)
19	Activated rosin flux
20	Proprietary flux

ship between their corrosiveness and their electrical conductivities as shown in Figure 3. W. W. rosin (Sample No. 1), as an example, is relatively nonconductive and reference to Table III shows that rosin in two separate tests is also noncorrosive. Similarly, the lower numbered rosin fluxes are in general poor in conductivity; in Table III they are all shown to be relatively noncorrosive while the flux samples which in Figure 3 are high in relative conductance are similarly shown in Table III as those which, in general, are correspondingly corrosive.

The general tendency of suppliers in this country and in Europe, to try to retain the admitted desirable properties of rosin but at the same time try to make it more active while also claiming that their particular proprietary products are still as noncorrosive as rosin, may be seen in the following statement from W. R. Lewis of the British Tin Research Institute where he confirms both our tests and experience in a single sentence, "Rosin flux may be made more active (and corrosive!) by additions of oleic or lactic acid; such compositions are:............." The parenthetical words including the exclamation mark are exactly as copied from Mr. Lewis' article published in 1948-49. In plain words, activating rosin makes it corrosive. Our tests show activating rosin makes it both conductive and corrosive.

TABLE III

Relative Corrosiveness of Various Fluxes Compared to W. W. Rosin on Copper Strips

Sample No.	12 hrs.	18 hrs.	31 hrs.	52 hrs.	152 hrs.	
	12 hr. 40% R. H. 75° F.	6 hr. 92% R. H. 75° F.	13 hr. 92% R. H. 75° F.	21 hr. 92% R. H. 80° F.	100 hr. 50% R. H. 80° F.	
1	a	a	a	a	a	Lab sample
2-3-5	a	a	a	a	a	
4	b	b	b	a	a	
6-7	a	a	a	a	a	
8	c	d	d	d	d	
9	b	b	c	c	c	
10-11	a	a	a	a	a	
12	a	b	c	c	c	
14	a	b	b	c	d	
15	c	d	e	e	e	
17	a	b	b	b	b	
20	a	b	b	c	d	

Note 1: a=No corrosion
b=Very slight corrosion
c=Slight corrosion
d=Progressive corrosion
e=Continuing corrosion

Note 2: See Table II for classification of "Flux Sample Numbers."

Water-White Rosin as a Flux

Since good electrical connections are the principal consideration of this article, it is the intention to show that, contrary to general belief, rosin is a good flux and *when properly employed* produces quick, easy and effective soldered electrical connections. The primary failure in the use

of rosin in the soldering process stems from a lack of understanding of the characteristics of rosin and its behavior under heat. This article, therefore, has stated the principles which, when properly applied in any soldering sequence, will invariably produce correct results.

Western Union has long been an exponent of soldering with rosin as a flux, as are some of the largest communication and electronic companies in this country. The Western Union and the Bell System still specify and use rosin as the one and only standard flux because no other fluxing agent developed to date equals rosin in low conductivity, absence of corrosion and, in general, effectiveness.

Rosin is available in 12 standard grades but only one of these grades is satisfactory for use as a flux. This grade is water-white, or W. W., rosin. A review of rosin as a flux will show it has the following favorable characteristics:

1. It possesses a natural acid which is not apparent at normal atmospheric temperatures.
2. It is satisfactory as a flux.
3. It has a low temperature of application.
4. It melts at a lower temperature than the solder solidus temperature.
5. The flux residue is electrically nonconducting.
6. The flux residue is noncorrosive.
7. The flux residue is nonhygroscopic.
8. The residue is hard and glassy smooth and, therefore, does not hold or collect dust particles.

In the foregoing list of rosin characteristics, it was stated that rosin does contain an acid. Technical literature on soldering tends to bypass the question of rosin containing an acid as though there were some mystery about it. The excuse that rosin lacks an acid makes it seem necessary to employ other and more active fluxes. But nature gave in W. W. rosin an acid with perfect fluxing properties which is inactive and apparently chemically inert at normal atmospheric temperatures because it is locked into the molecular structure of the rosin.

For the flux constituent of rosin to become active, the temperature must be raised in order to free and volatilize the acid constituent. This action begins at temperatures as low as 300 degrees F, while at 550 degrees F the acid portion is volatilized almost completely. Between these temperatures rosin will produce an excellent fluxing action if the flux is close to the metal surfaces being joined, but above 550 degrees F all of the acid portion will be rapidly freed and rapidly dissipated. When rosin is applied at temperatures above this point, it will have little, if any, fluxing action available for soldering, and if the temperature is sufficiently high a carbon deposit will be formed that will impede soldering.

Solders which are supplied with multiple cores or channels of rosin, or with a concentric ring of rosin, provide a measure of protection against human error in the application of rosin flux in that some portion of the flux unaffected by accidentally applied excess heat will be available at the surfaces being soldered.

Circuit Performance With Rosin

The performance of most types of electrical circuits is dependent to a great extent on the flux used in making the electrical connections. It has been shown that even the increase in relative conductance of an adulterated rosin flux which tested 48 percent (See Figure 3 Flux Sample No. 7) was sufficient to affect seriously the performance of high-frequency test apparatus. Fluxes of the chloride paste type showed an increase in conductance of 975 percent over that of rosin and thus was responsible for nullifying the functioning of photoelectric cell circuits, making inoperative Telefax recording circuits, and causing the malfunctioning of teleprinter and reperforator circuits and component parts of less sensitive circuits. Sample No. 14, a "high grade water white rosin, homogeneously activated" flux, shows an increase of about 1850 percent in conductance over that of unactivated rosin.

What may be accomplished with the use of rosin when properly used and controlled may be seen in the reliable statistics of a concern wholly adapted to its use

and controlled application. The Western Electric Company uses a bogey of one loose or defective connection per 10,000 connections in normal work and one in 20,000 in special types of work. On the other hand, a large electronic organization at a recent symposium on electrical connections provided statistics on their production which, when calculated on a comparable basis with the foregoing figures, indicate 763 defects per 10,000 connections. Even the foregoing is not a true comparison since the W. E. bogey of one in 10,000 was exceeded in actual production with an average for the past year of less than 0 7 per 10 000. This, of course, is still only part of the true picture since all of their soldered connections, having been made with rosin, have not and will not be the cause of circuit failures, interruptions or operational errors due to electrical conductance of the flux residue in the circuits, between the circuit components or between the circuit and ground, nor will any flux corrosion cause faults in stranded wire, at relay connections, litz wire or coil terminations.

Errors of High-Temperature Soldering

The use of too high temperatures in applying rosin has led to the erroneous belief, (a) that rosin is a poor flux, and (b) that a substitute flux which will withstand higher temperatures is necessary. These errors are the first stepping stones to the use of activated rosin fluxes, chloride type fluxes or proprietary fluxes. The reason for this is that the chloride type of flux *begins* to be active at the approximate temperature where rosin *ceases* to act as a flux. Hence, high temperatures of application appear always to give a *fluxing* action with chlorides, whereas too high a temperature destroys the fluxing action of rosin

Another error leading to the misuse of rosin began during the early days of World War II with the introduction of the so-called "high melting point" war solders. The name "High Melting Point" solder, erroneously attached to the 21-percent war solder for general use, gave rise to the belief that it required higher soldering temperatures. It then seemed only natural to conclude that higher temperature irons or similar heating devices were necessary. This reasoning was wrong, as will be shown later, because in the first instance no tin-lead solder alloys, except one, has a "melting point," and second, the solidus point temperature of war solder (21 percent) was the same as prewar solders while the liquidus point temperature was only about 90 degrees F higher than the normal prewar solder. Having arrived at these two incorrect bases for higher temperature soldering, it seemed natural to arrive at the conclusion that chloride fluxes must be employed, since, as previously explained, chloride fluxes only begin to be active at about 510 degrees F. Thus, the so-called benefit of a chloride flux appeared to go along well with the war solder theory

High temperatures, in addition to destroying the fluxing properties of rosin, are apt to cause oxidation of the surfaces to be soldered and thus further impede soldering

Another serious and costly effect of too high soldering temperatures is that even if the solder on the connection has "taken" properly, any object being soldered must cool off from the maximum temperature to at least the solidification point of the solder before the connection can be moved. The solidus point of 35-percent tin solder is 361 degrees F, so if a connection is heated unnecessarily to approximately 760 degrees F, the joint must cool until it reaches about 300 degrees F before it is safely intact, which would require 460 degrees F of cooling time. On the other hand, if the solder has "taken" between 500 and 550 degrees F, the cooling time would be only 200 to 250 degrees F as compared to the 400-degree-F differential. The latter not only represents a production or labor saving factor but serves to illustrate still another point. If the connection is moved at the solidus temperature it will become defective, whereas to move it either above or below this temperature will not appreciably affect it.

Overheating or high-temperature soldering results in a further reaction, since 500 to 800 degrees F will also char or

injure the insulation of most types of wires, while temperatures of half these values will injure plastic insulation. Wires lying on crossbars inches back from the soldered connection have been injured by elevated soldering temperatures so as to cause failure afterward in service entirely separate from the soldered connection. High temperatures will further injure and "burn" the tips of the soldering irons and thus retard the proper transfer of heat from iron tip to the connection.

Low-Temperature Application

Low-temperature soldering when properly applied brings out the full fluxing properties of rosin which, in turn, as previously explained, leaves a flux residue that is not harmful but *actually beneficial* to the electrical connection. Low temperatures also reduce the cooling periods and reduced cooling periods increase production and decrease labor costs.

In addition, the low-temperature application eliminates surface oxidation at the joints; confines the soldering temperature to the joint; lowers the lug and crossbar temperatures; eliminates injury to the insulation of the wires; reduces the cooling period to such an extent that danger to the soldered connection, due to movement, is almost eliminated; eliminates both the necessity and desirability of chloride or activated fluxes, and thereby eliminates the tragic sequence of resultant errors in electrical failures, erratic performance, circuit delays, operational errors, reduction in circuit efficiency, and so forth

Metal Surfaces

The surfaces of the metals to be soldered are extremely important. In fact, some authorities, such as S. J. Nightengale of the British Non-Ferrous Metals Research, have said that successful soldering depends upon three rules, which are cleanliness, cleanliness cleanliness. But this applies to a proper metal "capable" of being soldered. The question then arises, what surface is capable of being soldered and what flux should be employed? Because surfaces are important, some authorities have stated that fluxes are relatively unimportant while others specify fluxes as being of paramount importance. Actually many metals can be soldered successfully with rosin correctly applied if the surfaces are properly treated. The following metals can and should be soldered only with rosin in all cases where electrical circuits are involved.

Tin, hot-dipped, is one of the most desirable surfaces to solder, while tin electroplated is, to the contrary, very undesirable, particularly where thinly plated. Solder hot-dipped is also a very desirable solderable surface.

Cadmium is a commonly encountered surface where electrical connections are involved, but cadmium plate is good to solder to only when new and when plated with a relatively heavy plate. Cadmium surfaces are puzzling because of numerous changing factors. Parts purchased as "new" are often received with the surfaces dull, and such surfaces are very difficult to solder. This surface often corrodes into a powdery substance making it impossible to solder except by complete cleaning which in many cases means cleaning down to the base metal.

Copper, brass, or phospher bronze can be readily soldered provided the surfaces are made clean and bright prior to soldering. The phosphor or tin bronzes should always be cleaned immediately before soldering.

Beryllium bronze can be soldered but it should be understood that it is normally received with a heavily oxidized surface due to the heat treatment usually applied to this particular alloy. This surface must always be scraped clean immediately before soldering.

Dull nickel and nichrome can be soldered with rosin but the surfaces must be scraped clean and bright and given a coat of rosin alcohol solution immediately. The surfaces should next be tinned and the connection then soldered. Nichrome wire should not, however, be soldered where the operating temperature of the wire will exceed 300 degrees F.

Silver, silver-plated, or gold-plated surfaces may be soldered when they are clean and bright. Silver quickly discolors with oxygen and particularly fast in the presence of sulphur. These surface formations must always be removed before soldering. The removal of either coating is, however, quite easily accomplished.

Heating Devices for Soldering

Heating devices for soldering have been designed primarily from the standpoint of producing plenty of heat. Most designers have been advised that to solder considerable heat is required; that is, high temperatures and rapid heating. The result has been that electric soldering irons have been designed on this basis and the same idea applied to more rapid heating or to higher temperature devices. The gun-type soldering device is one example, the carbon electrode is another, and flame-type devices are still another. Thus, the range of heating devices begins with iron temperatures of 750 to 800 degrees F and continues up to flame temperatures of 2200 degrees F.

It is obvious that to solder it is necessary to heat the object up to an adequate soldering temperature but it has been seldom recognized that temperatures higher than necessary are detrimental and even disastrous in most branches of the electrical field. But the puzzling part is that, in addition, it is uneconomical to solder in this manner.

As previously shown, solders, fluxes, and metal surfaces are all adversely affected by high temperatures; in addition even the device used for transmitting the heat is often similarly affected. In the case of the soldering iron, if too high a temperature is employed, the tip will quickly become corroded, caked with scale, and pitted, all of which tend to prevent the quick transmission of heat to the article being soldered and to prevent the solder "taking" to the metal

The wattage of an iron of course expresses its capacity, but it is seldom recognized that using too large a capacity iron for a particular piece of work results in the iron temperature rising higher than normally required. An iron of too small capacity, on the other hand, makes the soldering slow, protracted and even impossible in some cases. The capacity of the iron should be of that wattage which will provide a sufficient quantity of heat (BTU) to bring the object being soldered quickly up to temperature, plus that quantity of heat absorbed by the object being soldered which must be replaced in the iron in the interim between soldering operations.

Where operations are interrupted or are not continuous, a temperature regulating stand should be employed to keep the iron only up to soldering temperature, or a resistor should be cut into the iron circuit to limit the current sufficiently so as to maintain only the minimum soldering temperature when not in use, and to remove the resistor in order to restore the current when soldering is resumed to that temperature required for continuous soldering operations.

In the use of rosin flux, it is fundamental that the heat should always be applied to the base metal and the solder melted by the heat in the base metal. The transfer of heat from the iron point to the connection may be accomplished quickly if a small globule of molten solder is maintained on the tip of the iron.

Conclusion

Soldering might seem to be too simple and familiar a topic to write about, but its extensive use and *its even greater abuse* make it a subject of very great importance. Abuses in the soldering of electrical connections in circuits have ruined many electronic and other sensitive electric devices or apparatus, puzzled engineers because of the erratic performance of many of their pet projects, caused numerous headaches in production, reduced operating circuit efficiency, and caused large increases in both installation costs and maintenance charges. The saddest part of this situation is that, in most cases, the cause of the troubles was either never known or never understood, while the trouble itself was wholly unnecessary and could have been removed in a very simple

manner The real paradox, however, is that these conditions continue to exist when all the difficulties could have been, and can be eliminated, not only at no increase in cost but actually at an appreciable saving.

The author is grateful to many of his colleagues for assistance in making this paper possible but wishes to thank B. L. Kline of the Chemical Research Laboratory in particular

A. Z. Mample, Assistant to the Lines Engineer, was graduated from Mechanic Arts Jr College (M A) and after entering Western Union service continued his engineering studies at the University of Minnesota In 1916 he was appointed District Plant Engineer at Minneapolis in which capacity he represented the company before state and city regulatory bodies, and assisted the U S. Bureau of Standards in drafting the first National Electric Safety Code Mr Mample left Western Union in 1922 to engage in his own electrical contracting business but returned by invitation in 1924 His major undertakings have included coaxial cable design and improvement of methods and apparatus for gas pressure testing and fault location in aerial and undergound cables and for cable splicing, he has done extensive research on toxic and explosive gas detection, electrolysis, soldering, brazing, and thermo-electric current generation developing practices and apparatus in these fields Mr Mample is the author of several technical papers and has assigned 26 patents to Western Union He is a licensed Professional Engineer and a Consulting Member of the Electrical Section, Association of American Railroads

H. F. KRANTZ, II, Engineer, Electronics Applications

Maintaining Carrier Translating Frequency Stability

TRANSLATING frequencies are those frequencies employed by Western Union to shift either a group of telegraph carrier channels from one position in a voice-frequency band to another, or to shift whole voice bands within a larger frequency spectrum.

In an article previously published in TECHNICAL REVIEW,[1] Messrs. T. F. Cofer and R. C. Taylor discussed the design of a frequency source whose accuracy met the exacting demands of a "secondary standard" for use in Western Union's expanding carrier system. Mass produced, with the design accuracy of one part in one hundred thousand, Standard Frequency Generator 6516 has been installed as the submodulator carrier supply in virtually every carrier office.

These standard frequency generators were originally intended to be installed in several choice locations where their "standards" accuracy could be conveniently used to check periodically the translating frequency of Type 49 Oscillators. These Type 49 Oscillators were considered at the time of their design to be sufficiently stable, because their tuned networks were enclosed in a thermostatically controlled oven. However, the Standard Frequency Generator 6516 proved itself to have such superior stability and accurate output that it soon took the place of the Type 49 as the working unit. This substitution has been effected, using the Type 49 Oscillator as the stand-by or spare translating frequency supply.

Although this "standard" is far superior to any previously furnished frequency source it is after all only a "secondary" standard and, by definition, not perfect. This fact was soon discovered by the Operating Department when the units were first put in service. For example, two offices when checking their synchronism would note a discrepancy, and each having a well-advertised-in-advance "standard" claimed the other was out. While the arguments that ensued hardly rate journalistic attention, such occurrences served to point out the need for means to check precisely the "standard" when it first reached its destination from the manufacturer, and periodically during its service life. This article describes how the field check of this secondary standard is accomplished, thus maintaining close tolerances of the translating frequencies.

Frequency Is Checked Easily With Direct Connection

In the early days of carrier telegraphy, when two Western Union offices were directly connected with physical pairs of wire, it was possible simply to zero-beat a test frequency over a pair to maintain synchronism. One method is shown in Figure 1, which assumes that a test frequency which fits into normal carrier subbands has been chosen. The office requiring a test, hereinafter referred to as the test office, patches any convenient test frequency, say 1000 cycles, simultaneously to each of the subbands of the band whose translating frequency is to be checked. The modulator at this office is shown to have a carrier frequency two cycles high,

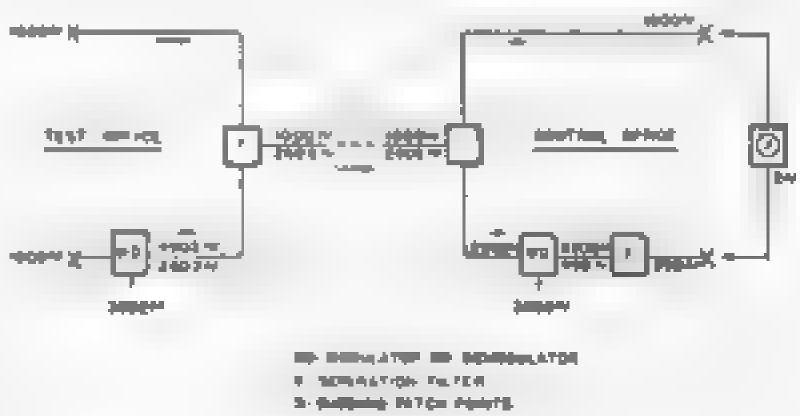


Figure 1. Synchronism with carrier pair between control office and distant end

which produces upper and lower sidebands of 4602 cycles and 2602 cycles, respectively. The upper sideband is blocked in the separation filter, while the lower sideband is transmitted to the line pair along with the original test frequency from the unmodulated subband. These two frequencies arrive unchanged at the control office where, after being amplified, the two frequencies are separated; 1000 cycles direct to the unmodulated subband jack and 2602 cycles to the demodulator. Presumably, this being the control point, the demodulating translation frequency is correct, and the output of the demodulator is 6202 cycles and 998 cycles. After the upper sideband is filtered out, 998 cycles are compared with the unchanged original 1000 cycles. The two-cycle difference is immediately apparent, and the control office directs the test office over separate talk facilities what correction to make on the frequency adjustment control of the oscillator until a zero beat is produced.

Intermediate Carriers Introduce Problem

This is all fine, but examination of Figure 2, where an intermediate carrier has been introduced, will show the reasons why such particular attention has been given the alignment and synchronism of the carrier system oscillators. This figure represents more often than not the true picture of carrier operation where the "line facilities" consist of a band, or portion of a large frequency spectrum, of a radio relay or service leased from another company and derived by modulated steps much the same as Western Union stacks its subbands to acquire a full band. These intermediate frequency modulations are beyond the control of Western Union personnel, and may not be exactly on their correct frequency at the time Western Union technicians wish to check the accuracy of their translating frequency

In Figure 2 the test procedure is the same as if only Western Union facilities were available, but the test frequencies may arrive at the control office changed by the allowable tolerance of the intermediate carrier. For purposes of illustration, it has been assumed that the test office carrier frequency is correct, and that the intermediate system is off by one cycle After separation and demodulation, 999 cps and 1001 cps are compared showing a 2-cycle beat. The adjustment of the oscillator at the test office this time, while resulting in zero beat, gives a false sense

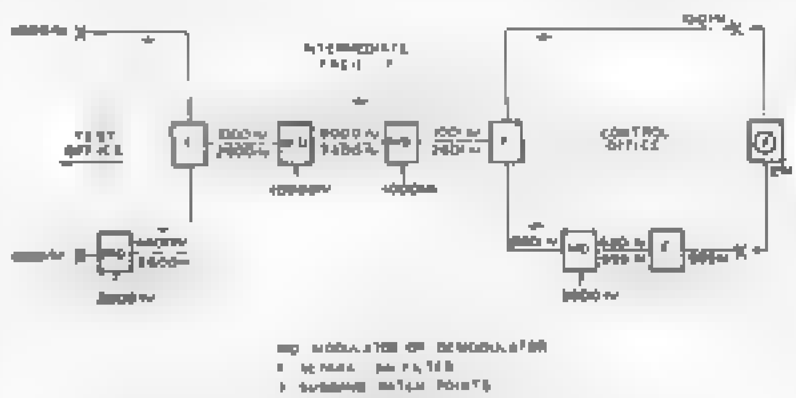


Figure 2. Synchronism with leased facility between control office and distant end

of security, since all channels are actually one cycle off. When unknown to Western Union the intermediate facility is readjusted to perfect synchronism, the channels of the modulated group go off two cycles! These frequency differences of one and two cycles, while seemingly insignificant to the 3600-cycle carrier, are particularly troublesome when referred to the channel frequencies of 375 to 1575 cps. Each cycle loss in system synchronism results in points loss on a teleprinter range scale, and compounding errors through band and subband patching can result in troublesome operation for each individual customer.

Synchronism Regardless of Line Facilities Necessary

The problem therefore was to devise a means to compare accurately a single frequency transmitted over each subband with immunity from the inherent minor deviations in accuracy between the test and control offices. Here the designers of Standard Frequency Generator 6516, apparently looking ahead to such a requirement, solved half of the problem immediately. By arranging for the device to produce *two* frequencies, 1000 cycles as well as 3600 cycles (see Figure 3), a test frequency and a translating frequency,

both derived from the same lower-frequency fork oscillator, are provided. The *difference* between these frequencies is now an exact quantity related to the frequency of the fork. Thus the nominal 1000-cycle test frequency is five times, and the nominal 3600-cycle translating frequency is 18 times the fork frequency The difference between these is then 13 times the fork frequency hence even a small change in the fork frequency is reflected at once into a large change in the difference frequency. Furthermore, both the test frequency and the difference frequency lie on the normal carrier sideband spectrum, one in the lower subband and one in the upper.

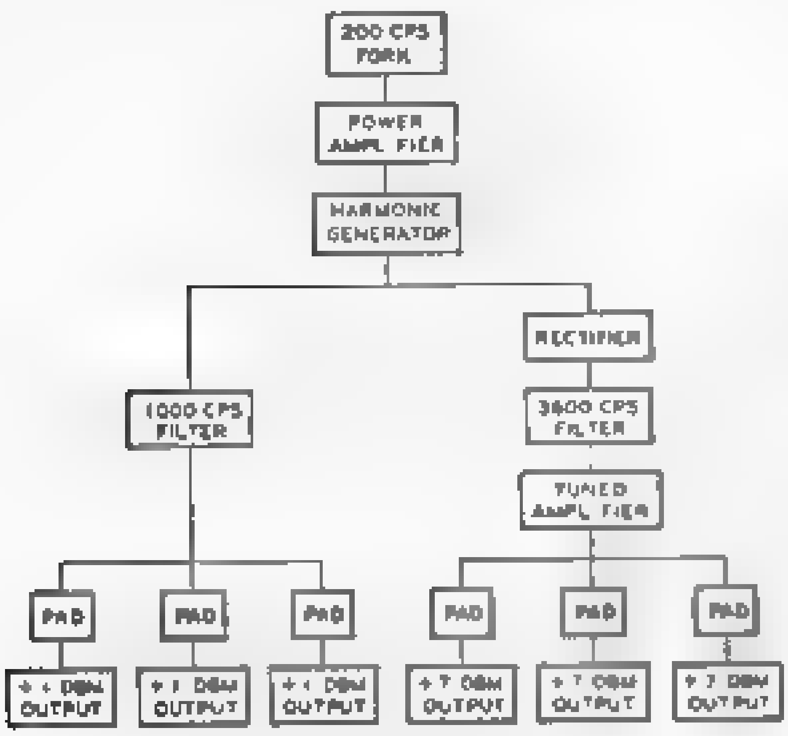
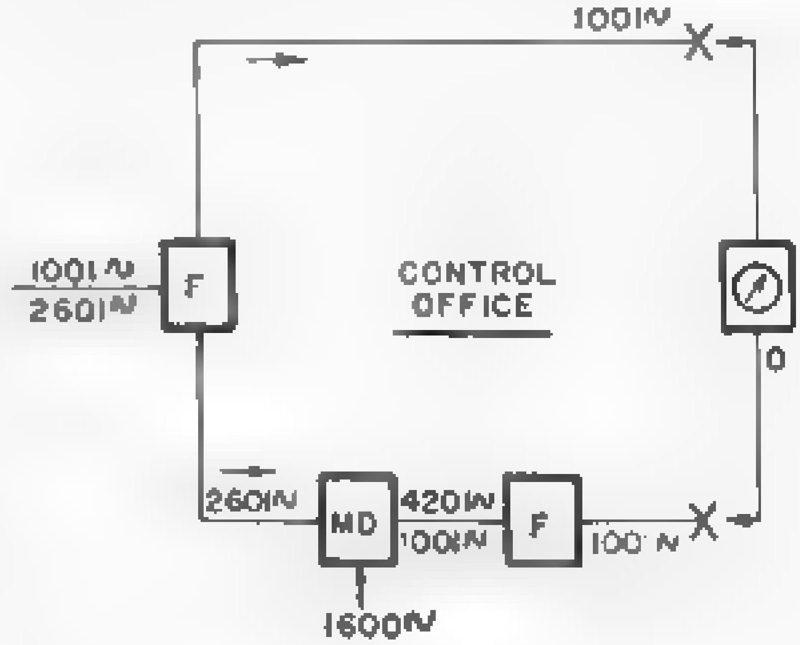


Figure 3. Block diagram of Standard Frequency Generator 6516-A

In Figure 2 it will be noted that, if the test frequency and translating frequency at the test office are assumed to be taken from the same standard frequency generator, the difference frequency and the test frequency arrive at the control office each altered the same number of cycles by the intermediate carrier facilities. At the control office the *difference* between these two frequencies is still correct, indicating that the standard frequency generator at the test office is correctly adjusted. Equating the two incoming frequencies by means of a standard 3600-cycle translating frequency, however, gives an erroneous result. What is required is to provide the control office modulator with a translating frequency related to the true difference between the frequencies arriving from the test office, which is 1600 cycles. This is shown in Figure 4 where, with a 1600-cycle carrier frequency, the lower sideband output of the demodulator produces



MD-MODULATOR OR DEMODULATOR
F-SEPARATION FILTER
X-SUBBAND PATCH POINTS

Figure 4. Demodulation with 1600-cycle carrier frequency

a zero beat with the arrived tone on the unmodulated subband. Only one small problem is apparent with this figure,—where to get an absolute 1600-cycle modulating frequency.

Standard Frequency Generator 6516 Provides 1600 Cps

The Standard Frequency Generator 6516 naturally is the ideal source of the 1600 cycles, being of "standard" accuracy and having its output provided by harmonics of 200 cps. By making a small change in wiring and deleting one of the 3600-cycle outputs, the even multiples of the 200-cycle pulse frequency are brought out with sufficient magnitude to be selectively filtered, giving a reasonably pure sine wave of 1600 cycles. This can then be applied in the usual manner through a square wave amplifier to the modulator.

Figure 5 is a block theory of this arrangement, known as the 3.6-KC Frequency Standard Comparison Unit, shown pictorially in Figure 6. A permanent installation at the control office with jacks at the test board provides for easy operation and simplicity when making the tests. As shown in the photograph, the various units making up the comparator are installed in spare spaces on an equipment rack

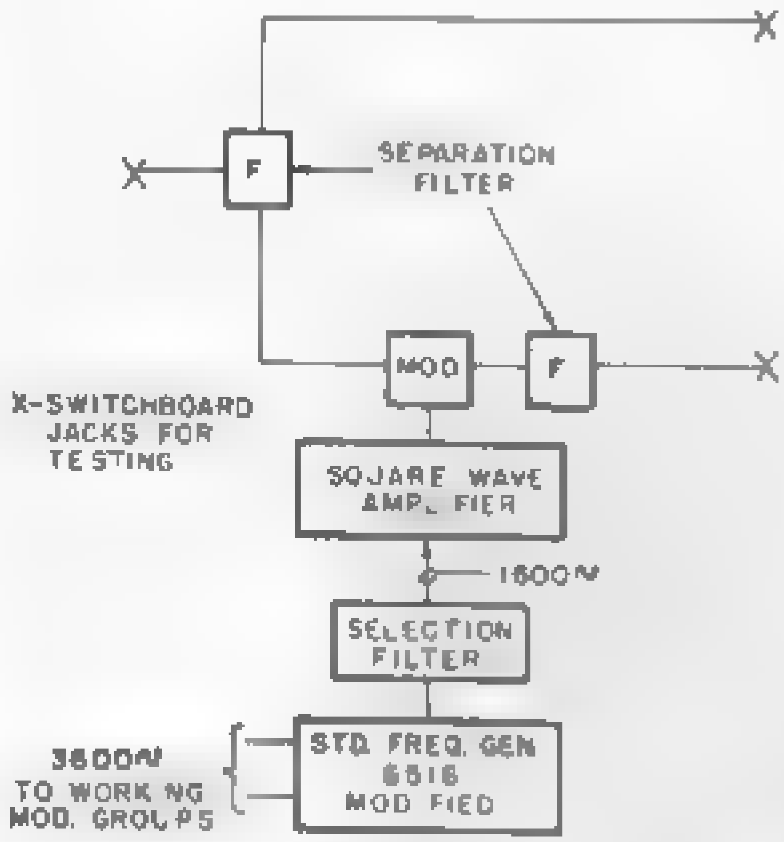


Figure 5. 3.6-kc frequency standard comparison unit—block theory

Installation at New York and Procedure

In order to provide maximum usefulness and flexibility the comparison unit was installed at New York's Testing and Regulating Room, for two reasons: (1) New York has carrier facilities to every major office in the nation, simplifying the setting up of temporary traffic arrangements when checks on the far-flung standard frequency generators are made; (2) periodic precise checks of the generator used for the comparison unit can easily be made with the Engineering Department laboratory standard. Assuming this has been done the precision checking of a given generator in the field becomes a simple routine. The office requiring a check of its Standard Frequency Generator 6516 requests a circuit to New York by message or on the dispatcher's wire When possible and convenient to both the test office and New York, the dispatcher assigns the moves necessary to clear the needed facilities for test and talk. The test office patches 1000 cycles to each subband (using the "D" carrier channel path if it is not possible to clear a whole subband), and then as directed over the talk facility by New York adjusts the basic fork frequency until zero beat indicates exactly 3600 cycles from the standard frequency generator, and New York gives the OK.

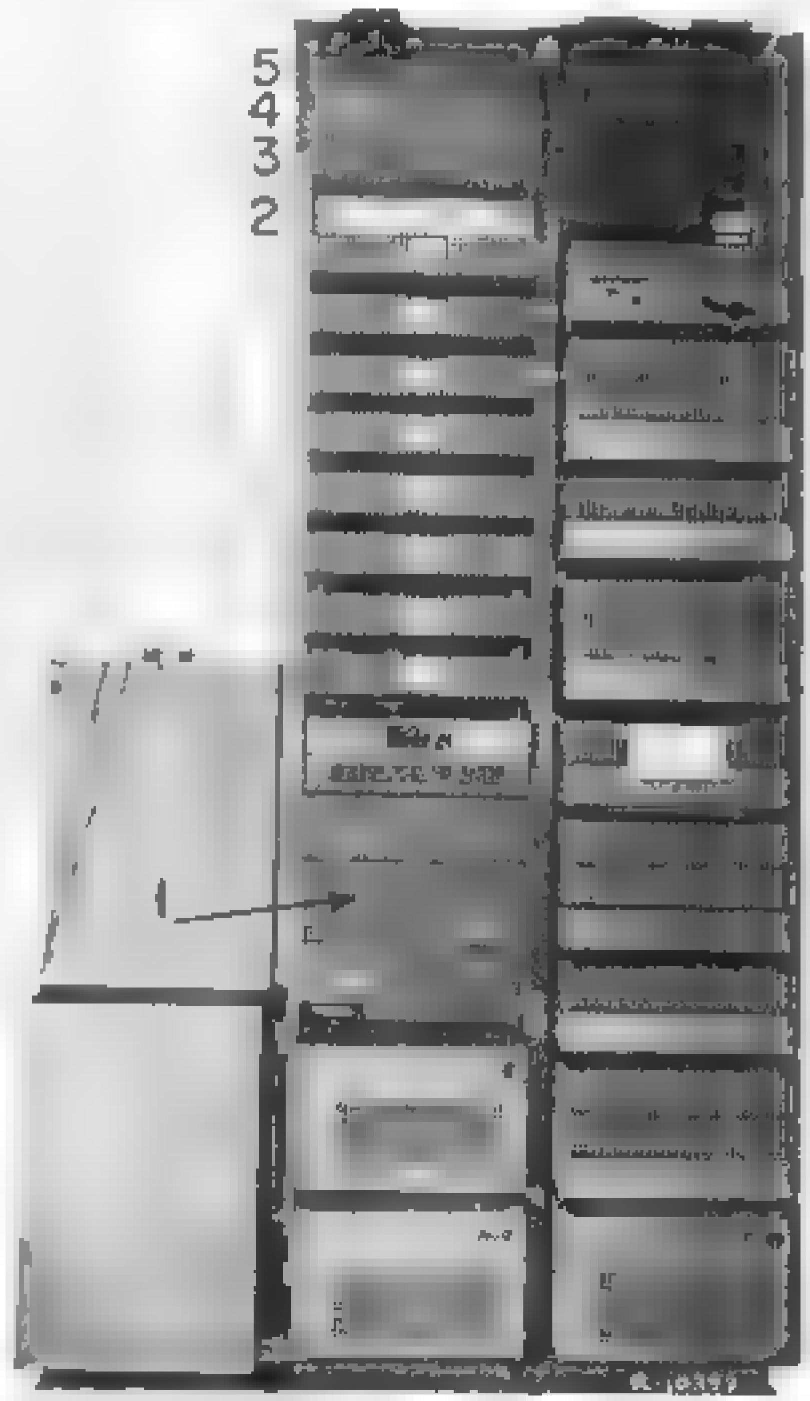


Figure 6. Standard comparison unit

1. Standard Frequency Generator 6516 with special connections
2. Filter for 1600-cycle frequency
3. Amplifier
4. Filter for 1000-cycle output
5. Comparison modulator, 1600-cycle carrier

Conclusion

Experience with this technique of frequency checking shows that Western Union can guarantee that service will in no way be adversely affected by carrier translating frequency instability. This speaks well for both the apparatus and cooperation of the dispatchers and technicians who deal with the carrier plant.

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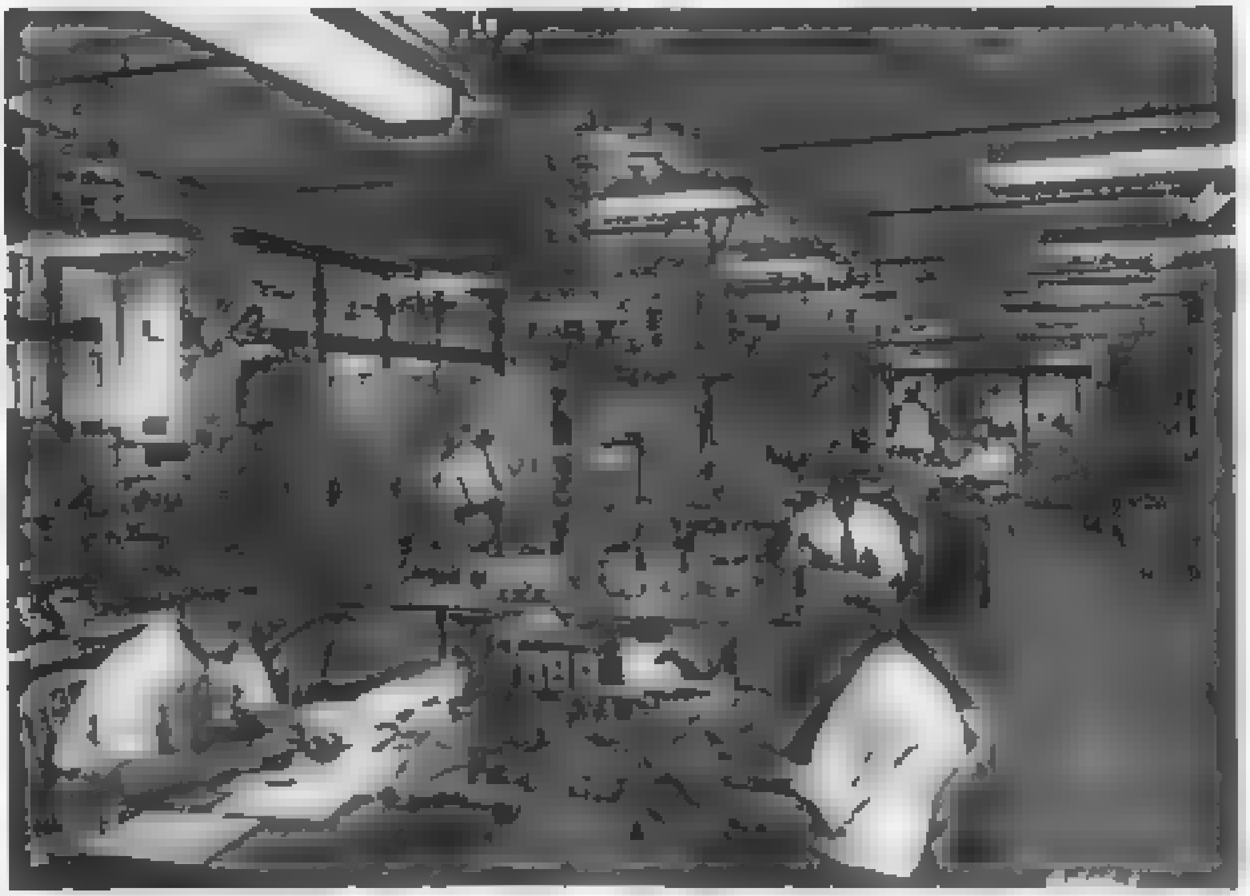
H. F. Krantz, II received his education in communications engineering at the Georgia School of Technology, and after serving with the U.S. Navy joined the Applied Engineering department of Western Union in 1946. Since then, his main work has been with the carrier systems, including the design of apparatus and preparation of assembly, installation and operating information. As a member of the Electronics Applications Engineer's staff, he has also assisted in the design of equipment for both ocean cables and landline d-c telegraphy.

Telegraph Research Laboratories, New York



A section of the Western Union equipment research laboratories at New York where new printing telegraph apparatus is continuously under development.

In one of the radio laboratories, experienced telegraph engineers design and test new terminal apparatus for extensions to Western Union's microwave systems.

CLAUDE W. JOHNSON, Engineer, Systems and Equipment

Concentrated Sending Position for Switching to Page-Printer Tie Lines

TELEGRAMS received at a Western Union reperforator switching center and destined for tie-line patrons are normally directed from the receiving positions to tie-line switching positions where they are manually switched to the patrons.[1] All traffic entering the Western Union reperforator system is in the form of tape printer copy suitable for reproduction on tape teleprinters. Hence, messages for patrons having tape teleprinters are transmitted in the form received. However, many patrons have page teleprinters in their offices. It is necessary, therefore, to insert carriage-return and line-feed functions and to translate certain other characters that are different in tape and page operation when transmitting to page teleprinters. These insertions and translations are performed automatically by tape-to-page translators.[2]

It is the purpose of this article to describe a recently developed arrangement whereby telegrams for as many as five heavily loaded page tie lines are switched from the main aisle receiving positions directly to a special line sending position which functions to transmit the messages automatically, in page form, to the appropriate tie line. This special sending position is termed a 5-Station Concentrated Sending Position for Page Tie Lines.

Switching to Tie Lines

Figure 1 is a block diagram which shows the principal equipments and cir-

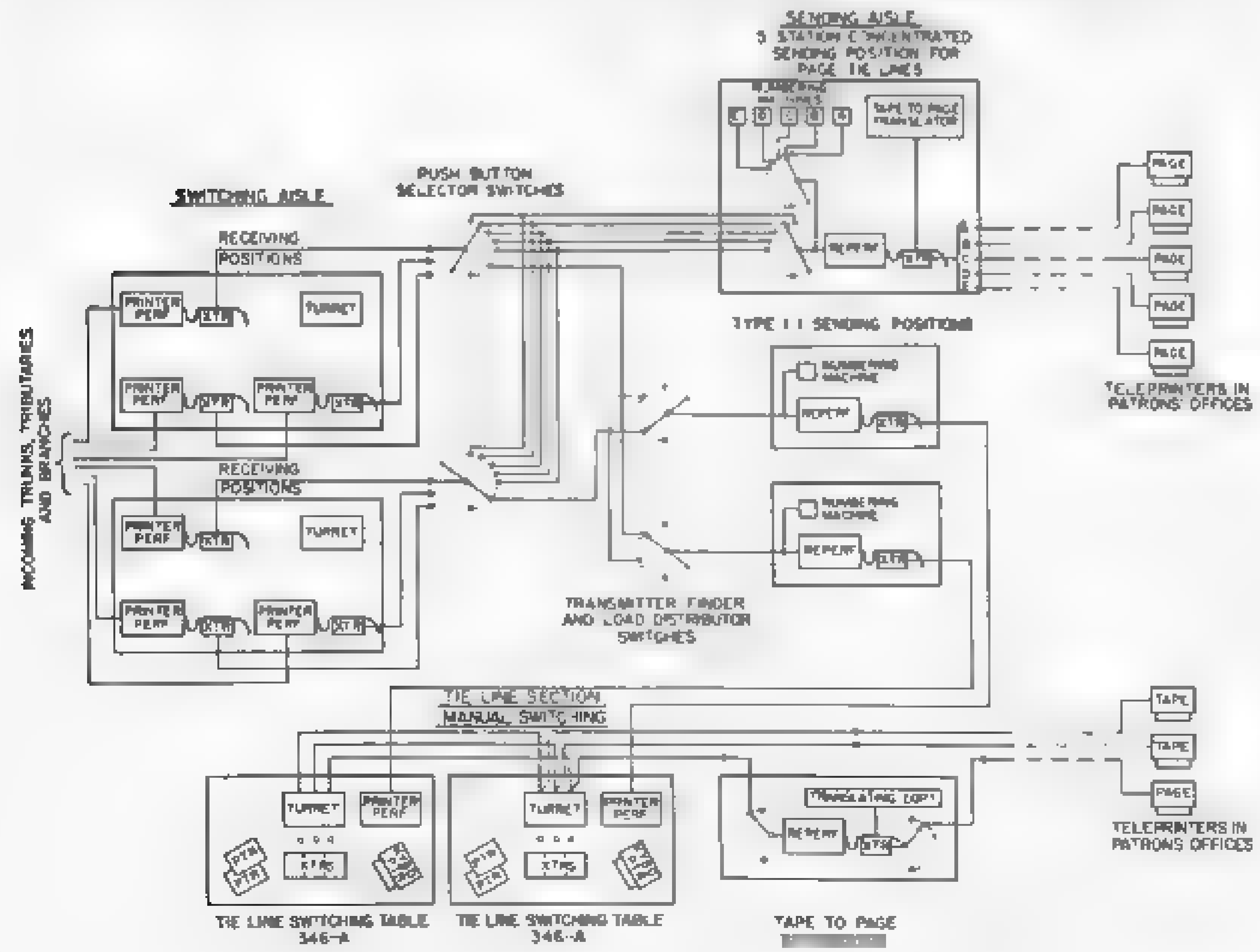


Figure 1. Flow of tie-line traffic through a reperforator switching office

cuits associated with the switching of tie-line traffic through a reperforator switching office. A major portion of this traffic flows through manual switching positions termed Tie-Line Switching Tables 346-A, shown in Figure 2. These tables provide facilities for terminating a maximum of 600 tie lines. At each table there are three

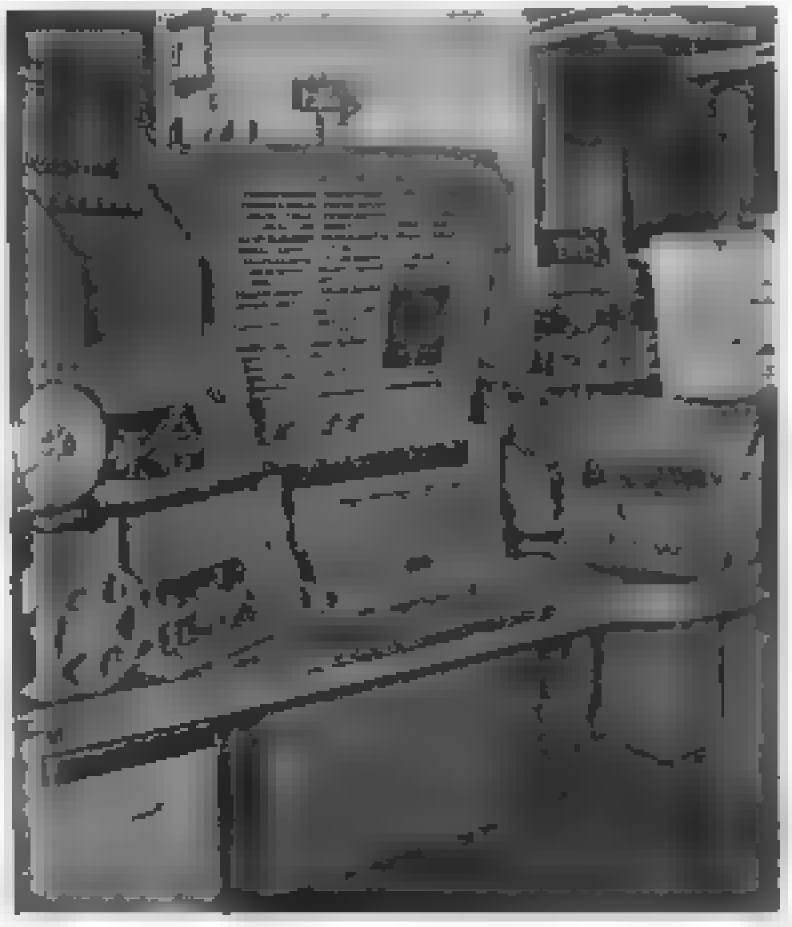


Figure 2 Tie-Line Switching Table 346-A

cord circuits including a 3-gang transmitter, monitor equipment and keyboard editing equipment to provide means for transmitting to the proper destination the messages received at the table on a printer-perforator. Tape-to-page translating equipment, which is common to all of the 346-A switching positions, is cut in automatically when a connection is established to a page tie line.

These manual tie-line switching positions provide a most versatile means for handling the traffic for such a large number of circuits having a relatively small message load per circuit and which involve a great amount of diversified switching instructions. It would not be practical from the operating point of view nor economical to terminate *all* such circuits directly in the reperforator system main switching aisle. However, studies showed that greater operating efficiency and an improved speed of service could be accomplished by switching directly from the receiving positions, via sending positions, to *some* of the *heaviest loaded* tie lines. In order to accomplish this economically, a special concentrated sending position was designed to serve up to five heavily loaded tie lines. Since such tie lines normally terminate on page printers, it was necessary also to provide tape-to-page translating equipment for this sending position

Sending Rack 7252

The 5-station concentrated sending position as shown in Figures 3 and 4 is known as Sending Rack 7252. A reperforator and associated impulse unit at the position serve to produce in perforated tape form telegrams switched from the receiving positions over cross-office circuits. An individual numbering machine is provided for each of the tie lines to number, sequentially, the messages directed to it. The appropriate number is prefixed to each telegram as it is reperforated. The perforated tape passes through a tape transmitter which transfers the code combinations punched in the tape to relay circuits for direct transmission or translation to line by the sending distributor

A Type 15 page teleprinter serves as a line monitor and records in page form each message transmitted to the tie lines. The signal indicator panel shown mounted on the shelf above the tape transmitter provides the necessary lamps and switches for controlling the various sending stop functions, line circuit closeouts, line connected indicators and connections to spill-over positions. The rotary switches and relay banks required for the operation of this position are gate-mounted on the rear of the rack shown in Figure 3. A resistor cabinet located at the bottom of the rack contains the necessary resistors, terminal blocks, line test jacks, circuit breakers, and so forth

Intra-Office Circuits

A separate cross-office circuit with its associated push button in each turret in the main switching aisle is provided for each tie line served by the 5-station con-

centrated sending position These cross-office circuits are terminated in a single intra-office reperforator at the sending position. A separate automatic numbering machine is provided for numbering the messages transmitted to each tie line over these cross-office circuits. When a cross-office connection is established from a main aisle receiving position intra-office transmitter to the intra-office reperforator at the concentrator sending position, a rotary switch functions at the sending

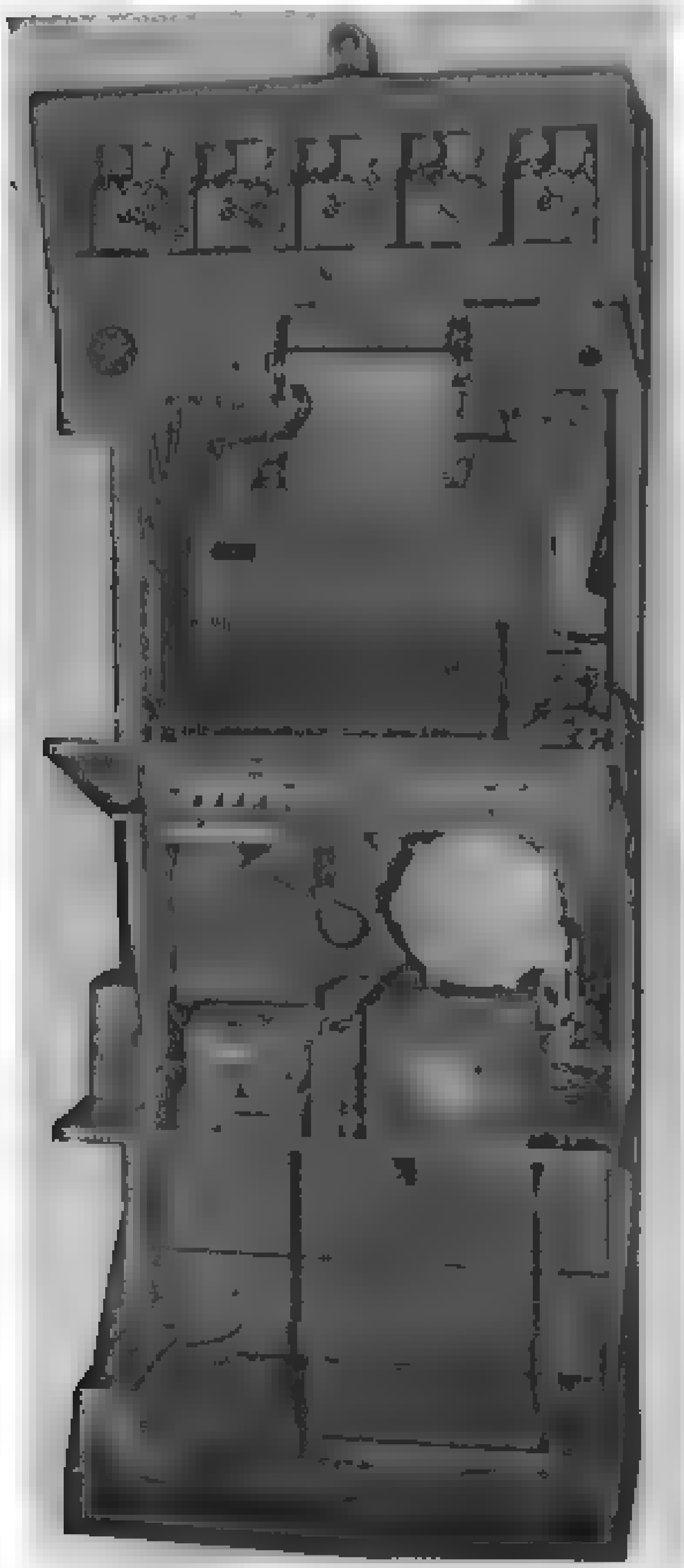


Figure 3. Concentrated Switching Position Rack 7252

position to connect the proper automatic numbering machine to the concentrator reperforator. Before transmission is started from the main aisle intra-office transmitter, the automatic numbering machine functions to send into the concentrator reperforator the call letters of the area center, a line selection character, and the message sequence number. The line selection character will be A, B, C, D or E, one of which is used to represent each of the tie lines terminated at this position. Following the operation of the numbering machine, the main aisle intra-office transmitter functions to transmit the message to the concentrator reperforator at the sending rack. When the double-period termination of the message is encountered, the connection between the main aisle receiving position and the concentrator sending position is released

Tie-Line Sending

The perforated tape from the intra-office reperforator passes through a tape transmitter, which sets up the code combination punched in the tape on five reading relays. As a message is advanced up to the pins of the tape transmitter, the first and second characters, which are the call letters of the area center, are idled through the transmitter. When the third or line selection character is encountered, the transmitter stops with this character resting over its pins. Contacts on the reading relays are arranged to read for this selection character and to provide a circuit for the operation of a line relay which terminates the tie line represented by this character.

The operation of a line relay connects the selected tie line to the sending distributor When the connection is established, the characters Carriage Return, Line Feed, Letter Shift, W, U, are automatically transmitted to the tie line. The transmission of the first three characters insures that the carriage of the patron's teleprinter is positioned for the beginning of a line. The characters WU represent Western Union and replace the office call letters of the area center that precede the message in the perforated tape. Transmis-

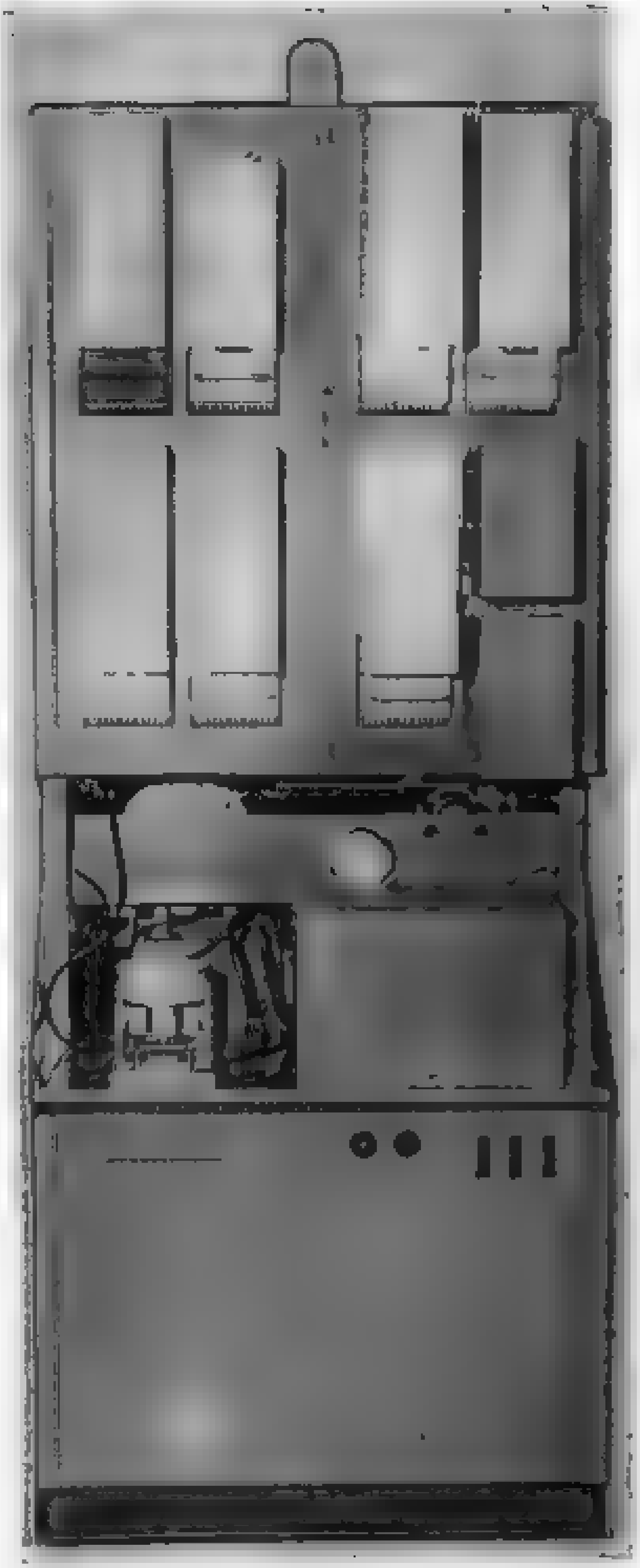


Figure 4. Rear view of concentrated sending position

sion is now initiated from the tape transmitter. The line selection character which was being held is transmitted to line first and is followed by the remainder of the telegram.

Tape-to-Page Translations

Each character stepped over the pins of the tape transmitter is examined to determine if the character requires any conversion for page reception. If no conversion is required, the character is transferred to a set of storing relays for transmission to line by the sending distributor.

However, if a character not common to both tape and page teleprinters is encountered in the tape, the translator circuits function to transmit the page equivalent of that character to line.

The following functions must be performed in order to convert the tape copy of the message to page copy:

1. Count a certain minimum number of characters (58) for a line and insert carriage return and line feed on the following space character. If a space character is not encountered after a count of 58 characters, a carriage return and line feed are inserted following the 69th character.
2. Convert any equals sign character into carriage return and line feed.
3. Convert the number sign (upper case equals sign) into upper case H.
4. Convert the apostrophe (upper case N) into upper case S.
5. Convert the paragraph sign (upper case S) into carriage return, line feed and five spaces.
6. Convert the percent sign (upper case M) into letter shift, PCT, figure shift.
7. Convert comma (upper case period) into upper case N.
8. Convert period into figure shift, M, letter shift.

When the double-period termination of the message is encountered, the first period is converted into figure shift, M, letter shift, and the second period into carriage return, line feed. A request is then initiated automatically for a time and date unit connection which serves to transmit to line characters such as (1100 AM OCT 1 55)=

Upon completion of the time and date transmission, a rotary switch device functions to transmit a carriage return and eight line feeds to provide spacing between successive telegrams. The line relay of the connected tie line is released immediately following this function, and the

perforated tape is stepped through the tape transmitter until the following message is encountered or until a taut tape condition occurs.

"Spillover" Positions

Occasionally, it is necessary to close temporarily a particular tie line to further traffic due to irregular office hours, equipment trouble, and so forth. In this event, the traffic for the tie line may be directed from the sending position to an auxiliary switching position termed a "spillover" position. This is accomplished by means of a spillover switch for each tie line provided at the sending position. At the spillover position, the messages may be rerouted for special handling to the particular patron or, if so instructed, held for retransmission when the circuit is reopened for traffic. Since it is necessary to retain the messages in tape form while they are in the reperforator system, the tape-to-page translating functions are omitted for messages transmitted to a spillover position.

Following extensive service trials in which the new concentrator performed satisfactorily, it has become available as a standard element of the Western Union reperforator system.

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1. Switching to Patrons' Teleprinter Tie Lines, R. S. WISHART and G. G. LIGHT, *Western Union Technical Review*, Vol. 3, No. 2, April 1949.
2. Tape-to-Page Translator, A. E. FROST. *Western Union Technical Review*, Vol. 3, No. 2, April 1949.

Claude W. Johnson graduated from Alabama Polytechnic Institute at Auburn in August 1948 with a degree of Bachelor of Electrical Engineering. After graduation he joined Western Union and was assigned to the Equipment Research Division of the Development and Research Department. Except for a period of service in the U. S. Navy in 1951 he has since been engaged in the development of semiautomatic and automatic switching systems for use by Western Union, private wire patrons and the Armed Services.

THE ADVANTAGES and possibilities of patents are of special significance to the engineer and scientist who have daily contact with machines, systems and processes. It is well known that a United States patent confers upon the patent owner certain exclusive rights over the invention that constitutes the subject matter of his patent. The present paper will consider the nature and limitations of these rights and the prerequisites of patentability

Since the inventor's rights are exclusive, a patent is sometimes referred to as a legal monopoly. However, since the term monopoly has sinister connotations, the distinctions between the patent monopoly and the general monopoly should be noted. Since the latter usually takes a right which should be available to all and conveys it to a single person, corporation or group, it is likely to be detrimental to the public and generally is prohibited by law, whereas the former has proven to be highly beneficial to the public. Because a patent will be granted only on an invention that had previously been unknown, the public is deprived of nothing that it had before the patent grant

The stimulation to new industries and individual enterprise and the public benefits derived thereby as a result of the patent system have long been recognized From the date that a patent is issued it is a public document and available to all. Copies of any U. S. patent can be obtained from the Patent Office at a cost of 25 cents per copy. Thus the patent grant has the beneficial effect of increasing the available technical knowledge and making known that which had been previously unknown. Another public benefit is that the invention falls into the public domain upon the expiration of the term of the patent, which is 17 years

Basically, then, a patent is a contract between the inventor and the public. As is common to all contracts there is mutual consideration—each party gives something to the other. The inventor gives the knowledge of his invention to the public when the patent is granted and relinquishes his exclusive rights after 17 years. In turn the inventor receives exclusive rights for the duration of the patent

Who Is Entitled To a Patent

Except in a few special cases only the person who actually devises the invention may validly apply for a patent. Thus, a person traveling in a foreign country who observes a device that has not been introduced in the United States could not obtain a valid patent since he would not be the inventor of the device.

The inventor is the person who conceives the basic idea of the invention even though he himself does not work out the routine design problems necessary to construct the device. The one who conceives a new circuit, for example, may employ electrical engineers to calculate the necessary values of the components for the proper operation of the circuit. Those who do the routine design and calculating work do not become joint inventors with the one who has the original idea. If, however, the original conception is little more than the statement of a problem to be solved and the inventive concept is evolved by those employed to solve the problem, the latter are the inventors and the patent application properly carries their names.

It is customary in research departments for engineers to work under the supervision of a project director. When an invention results, the question arises as to who is, in fact, the inventor. If the director plans the experiments, directs the day-to-day conducting of them, and interprets the results, then he is the inventor rather than those who perform the experiments. On the other hand, if the research director merely assigns a problem to an engineer who thereupon proceeds to devise a system or machine to solve the problem, the engineer is rightly the inventor.

Very often a number of engineers will work together on a new system. In such cases the question of sole or joint inventorship must be considered. If an inventive concept resides in one part of the system rather than the entire combination, and one of the engineers developed the inventive part, then he would be a sole inventor and the patent application would be in his name alone. Sometimes, however, two or more associates will work so closely together that their exchange of ideas and cooperation in the step-by-step development of the invention are so interleaved that they must be considered as joint inventors and the patent application would be made in both names.

Subject Matter of Patents

Not all new ideas and concepts may have the advantages of the patent law. The Patent Act specifically enumerates the classes of inventions upon which patents may be granted. The four principal classes of patentable subject matter are (1) process or method, (2) machine; (3) article of manufacture; and (4) composition of matter.

Process or Methods. The term process is synonymous with method and may be defined as an act or series of acts performed on subject matter to transform or reduce it to a different state or to obtain a desired result. A patentable process may be a series of steps for performing a particular operation, treating specific articles or material, making compositions of matter, or making specific articles.

An example of a process for performing an operation is set forth in a patent issued to a Western Union engineer and assigned to the company. The process is for testing a line circuit, both ends of which are supplied with a direct potential, and comprises the steps of "intermittently supplying a different fixed potential to said line, and measuring the potential at points along said line while supplying said intermittent potential." Another patent is for a process of controlling the arc discharge in a gas and consists of the steps of "rendering conductive the arc path between two electrodes, establishing in the arc path a negative electrostatic field which completely envelopes one electrode and having a potential high enough to form a closed sheath of positive ions to thereby extinguish the arc." It should be noted that patentable processes are not limited to tangible results nor to a plurality of steps. A one-step process is found in Bell's original telephone patent, i.e., the method of "transmitting vocal or other

sounds telegraphically by causing electrical undulations similar in form to the vibrations of air accompanying the said vocal or other sounds."

Though the term process as used in the patent laws is broad, it has its limitations. Courts have declared certain operations to be outside the scope of the term and therefore not valid patentable processes. If the steps of an alleged process consist merely of operations that take place only in the mind, such as the steps of solving a mathematical problem, it is not subject to patenting. Nor are methods of doing business within the realm of patentable subject matter. Bookkeeping systems and cashier receipt checking systems fall into the excluded category of methods of doing business. In one case a claimed method of advertising "which consists in issuing publications or supplements distinguished from each other and publishing a series of advertisements some or all of which are accompanied by offers for certain publications or supplements" was held to be a method of doing business and therefore nonpatentable.

Machines and Articles of Manufacture. Machines of all types are subjects of patentability. The term includes not only the usual concept of machine but also any device with a movable part and a rule of operation. Devices that lack movable parts or comprise a single mechanical element fall into the class of articles of manufacture. This is probably the largest class since it includes all structures not included in the other classes. Obvious examples are hand tools, pieces of furniture, articles of clothing, and so forth. The size of the article is immaterial, for bridges, stadiums and roof structures have also been held to be articles of manufacture within the meaning of the term as used in the Patent Act.

However, large as the class of articles of manufacture is, it is not all-encompassing. Printed matter, such as a membership card, is not a patentable article of manufacture, on the theory that it is an abstract idea and structurally indistinguishable. Thus an author of printed material must look to the copyright laws for protection. Also, natural articles that are products of nature are not considered as patentable subject matter. This has been held to be true even though the natural article had been artificially treated. In one case an orange having a borax impregnated rind to resist blue mold decay was held by the Supreme Court not to be an article of manufacture.

Compositions of Matter. Compositions of matter include mechanical mixtures of materials as well as chemical compounds and may be in a solid, liquid or gaseous state.

In the interest of completeness it might be mentioned that two additional classes of patentable subject matter are provided, i.e., designs, which are based on physical appearance of objects, and plants which have been asexually reproduced. However, these classes are seldom encountered by the engineer and since they have special characteristics they will not be considered here.

Conditions Precedent

Before a patent will be granted, the alleged invention will be examined in the Patent Office to determine whether it fulfills the three basic requirements of utility, novelty and inventiveness.

A patent will not be issued on a useless device. Therefore a machine that is inoperative fails to meet the requirement of utility and is consequently unpatentable The classic example is the perpetual motion machine. When the Patent Office receives an application alleging a device capable of perpetual motion, the applicant is informed that it is contrary to the known laws of nature and that his filing fee will be refunded if he will withdraw his application. Of course, if the applicant insists, the Patent Office examiner will give him an opportunity of sustaining the burden of proving operativeness.

Perhaps all devices have utility in that they can be used as paper weights. However, such utility is not sufficient to satisfy the requirement of the patent laws. *The device must accomplish the result or objective for which it was intended.* Thus a paper-shredding machine which is inherently inoperative for this intended

purpose would lack utility even though it might make satisfactory cole slaw. This does not mean that the invention must operate in a highly efficient manner. The Patent Office does not set a standard of excellence of performance that new inventions must meet. The invention may be crude and inefficient but it must accomplish its intended purpose

Some devices, no matter how well they may perform their function, are held to lack utility if the function is frivolous, immoral or against public policy. The inventor who devises a new and better device for forging checks will find his patent application rejected as lacking utility no matter how useful it may seem to him. Inventions that are intended to work a fraud on the public, such as a method of sprinkling tobacco leaves with a solution to produce spots to simulate tobacco of a higher quality are held to be without utility.

The second requirement is that the invention must be new. *The inventor will not be given a patent monopoly if his invention is already known.* In considering this requirement there are two dates that must be kept in mind, namely, the date the invention is made and the date the patent application is filed

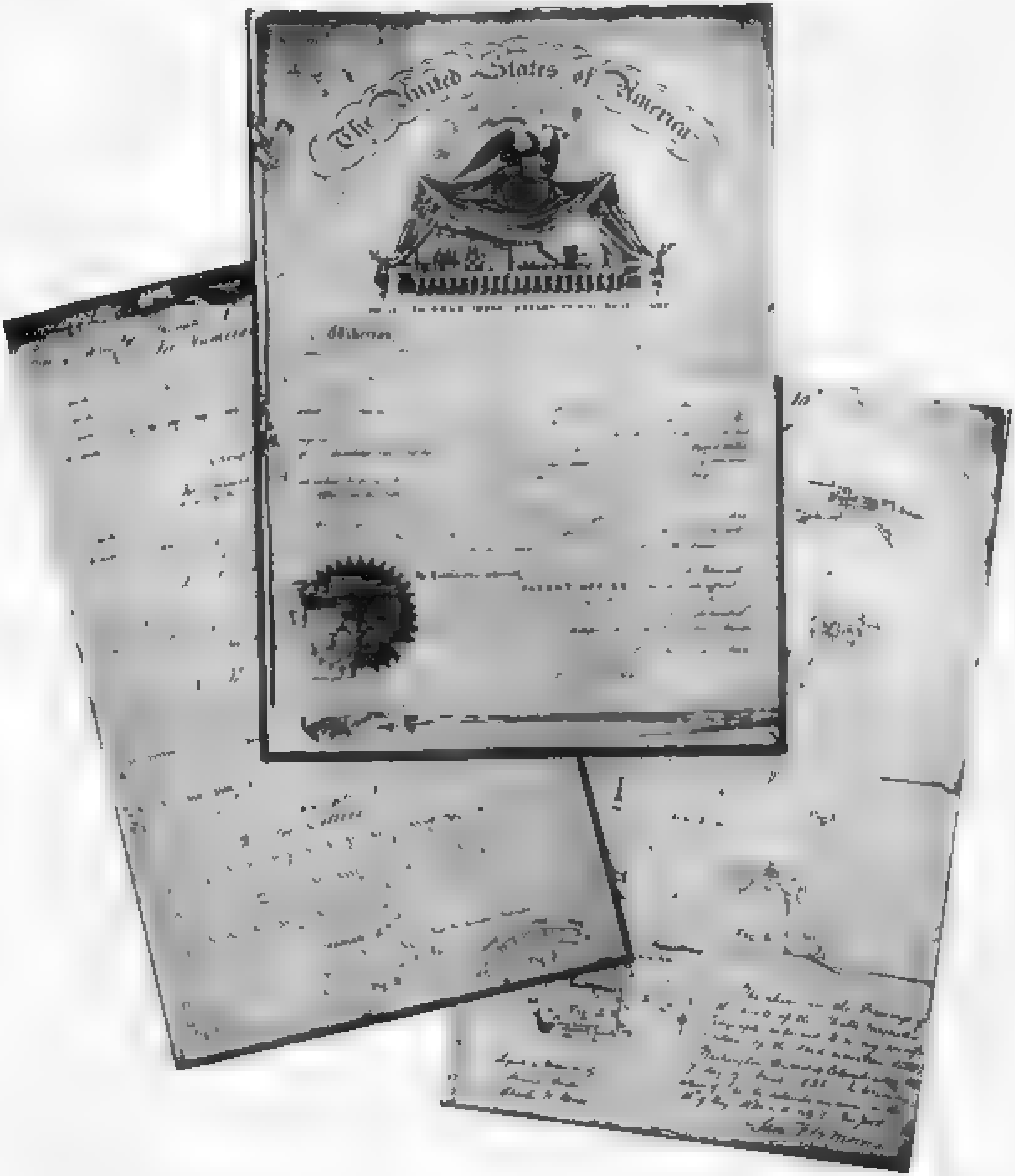
The application will be rejected if the alleged invention was known or used in the United States prior to the invention date. However, this prior knowledge or use must be accessible to the public in order to bar the subsequent inventor. If, for example, Smith invents a device which he maintains secret and then at a later date Brown independently invents the same device and promptly applies for a patent, Brown's application will be granted. Smith not only loses his right to a patent by suppressing his invention, but his knowledge or use of the device, since it was not accessible to the public, cannot be used as a bar against Brown. Mere prior knowledge or use in a foreign country will not negative novelty no matter how widespread the knowledge or use may be The subsequent inventor who applies for a U. S. patent will not be barred. Of course, he must have been ignorant of the foreign knowledge or use at the time he made his invention or he would not in fact be an inventor and, as pointed out above, only an inventor may legally file for a patent.

Though knowledge or use in a foreign country will not preclude a U. S. patent, a foreign patent or publication will. So the person who invents a device that has previously been disclosed in a foreign book, magazine, patent, or the like, will have his patent application rejected. This is based upon the assumption that the printed material and patents are available to the inventor and hence he is presumed to be familiar with their contents. Similarly, a U. S. patent or printed publication prior to the invention date of the subsequent inventor will also defeat his patent application. It is seen then that knowledge or use in the U. S. or a patent or printed publication anywhere in the world prior to the invention date will serve as a bar to a U. S. patent.

The filing date, that is, the day on which the patent application is received in the U. S. Patent Office, is the other critical date in considering the question of novelty. Even though an inventor is the first to invent a new device, if it has been patented or disclosed in a printed publication more than one year prior to the filing of his application, a U. S. patent will not be granted. This is true whether the prior patent or printed publication is in the U. S. or a foreign country. Therefore, if Brown is the first to invent a new system and presents it in a paper at a meeting of the IRE, he has a period of one year from the publication of the paper in which to file a patent application.

It is customary for professional societies to distribute preprints of a paper to members in advance of the meeting at which the paper is orally read. Subsequently, the paper is published in the society journal. The question then arises as to the publication date that starts the one year period within which the patent application must be filed. The society journal is of course a printed publication and if the inventor delays a year after the issuance thereof, he will forfeit his right to a patent. The oral reading of the paper as well as the initial submission thereof has been

PAGES FROM THE FIRST MORSE PATENT



This first patent dated 1840 was revised later, presumably to correct defective claims in the specification, and the patent was reissued. Morse, of course, in exchange for the revised "letters patent" returned the original papers to the Patent Office where they have been preserved for over 100 years. This patent is signed by the Commissioner of Patents, H. L. Ellsworth, whose daughter Miss Annie G. Ellsworth was the first to tell Morse that Congress had granted money for construction of the Washington-Baltimore line. In return Morse promised her, "When the line is completed the first dispatch sent upon it shall be yours." Her message read, "What hath God wrought!"

At the left is a page showing dot and dash codes as conceived by Morse, including the "type" forms designed for his "Portrule" transmitter.

A page of diagrams at the right shows the Morse register for receiving dots and dashes on a moving paper tape. As was customary Morse filed a "caveat" or preliminary statement some time before making his patent application. This is referred to in his handwriting at the bottom of this page, which reads as follows: "The above are the drawings of the parts of the Electro Magnetic Telegraph referred to in my specification of the said invention dated Washington, District of Columbia on the 7th day of April 1838. In testimony whereof I hereto subscribe my name on the 18th of May 1840 in the City of New York. Sam: F: B: Morse."

The title page at left reads as follows:

"Whereas Samuel F. B. Morse, New York, has alleged that he has invented a new and useful improvement in the mode of communicating information by signals by the application of Electro Magnetism which he states has not been known or used before his application; has made oath that he is a citizen of the United States, that he does verily believe that he is the original and first inventor or discoverer of the said improvement, and that the same hath not to the best of his knowledge and belief been previously known or used; has paid into the treasury of the United States the sum of Thirty dollars and presented a petition to the COMMISSIONER of PATENTS signifying a desire of obtaining an exclusive property in the said improvement and praying that a patent may be granted for that purpose.

"These are therefore to grant, according to law, to the said Samuel F. B. Morse his heirs, administrators or assigns, for the term of fourteen years from the twentieth day of June one thousand eight hundred and forty the full and exclusive right and liberty of making, constructing, using, and vending to others to be used, the said improvement a description whereof is given in the words of the said Samuel F. B. Morse in the schedule hereunto annexed and is made a part of these presents.

"In testimony whereof I have caused these Letters to be made Patent and the Seal of the PATENT OFFICE has been hereunto affixed.

"Given under my hand at the City of Washington, this twentieth day of June in the year of our Lord one thousand eight hundred and forty and of the Independence of the United States of America the sixty-fourth

John Forsyth, Secretary of State.

H. L. Ellsworth, Commissioner of Patents."

held by the courts not to be a printed publication within the meaning of the Patent Act. However, no decisions have been found on the question of whether the distribution of preprints constitutes a printed publication. Though it might be argued that such a confidential distribution is not a publication, the safest course for an inventor to follow is to have his patent application filed within a year from the distribution date.

Public use or public sale of the invention in the U. S. more than one year prior to the application filing date also serves as a statutory bar. This gives the inventor a one year grace period to test the marketability of his invention before he decides whether it warrants a patent application. However, the better practice by far is to forego this grace period and file the patent application before publication of the invention and before placing the new device on sale or in public use. Public disclosure could well serve to remind another that he also had conceived the device, and since the first one to file an application has distinct advantages in a controversy of priority, any act which might stir a possible adversary into activity should be avoided.

What Is "Invention"? The third condition of patentability and by far the most difficult to define accurately is "invention." In general it may be stated that a *new device constitutes invention if it is such an advance in the art or field to which it relates that others skilled in the field could not have devised it by routine procedures.* New devices are seldom entirely new pioneer inventions—there were incandescent lamps before Edison's. The vast majority of inventions are improvements of greater or lesser degree on similar prior devices. In determining whether a new device constitutes invention it is necessary therefore to compare it with the most similar prior devices as disclosed in prior patents and publications. The distinctive or novel features of the alleged invention are looked to in determining whether or not invention is present.

If the device represents merely a trifling advance, or one that might be expected in the normal development of that particular technological field or art, invention is said to be lacking. The new device must represent more than mere mechanical skill. Thus, a person might provide a mechanical stop for a moving mechanism. Although this feature might be new for the particular mechanism, such an improvement would not constitute invention since it involves nothing more than the ordinary ability of an artisan. Similarly, the provision of a holding cir-

cuit for a solenoid in a system wherein the solenoid had previously lacked a holding circuit would not amount to invention.

In attempting to define invention the courts have evolved certain negative rules. Invention is generally held to be lacking if the new feature of a device involves nothing more than one of the following: a change of degree or size, change of material, duplication of known elements, making a device portable or making an element adjustable. In one case a patent applicant for an electrochemical galvanizing process provided adjustable cathodes to vary the distance from the material being electroplated. It was held that adjustability of a well-known element involves nothing more than mere mechanical skill and therefore was unworthy of patentability.

Though these negaitve rules of invention may be generally stated, they have exceptions and cannot be applied with certainty in every case. The inventor who substituted celluloid for metal in a saltcellar received a valid patent although his invention involved only a change of material. Also providing a plurality of turbines on the same shaft constituted invention though it was only a duplication of known elements. The test to be applied is whether a new, useful and unobvious result is obtained. In the saltcellar case the problem of salt sticking to the cap was solved and in the turbine case an equalization of thrust was achieved. In deciding the question of whether or not a new device involves invention, prior decisions and general rules are of little value. Each alleged invention must be considered independently and judged on its own merits.

The Patent Application

When the inventor is satisfied that his device is perfected, he files an application for a patent with the U. S. Patent Office in Washington, D. C. The application must contain a complete disclosure of the invention which includes a detailed written description along with appropriate drawings. These must set forth the invention with such clarity that a person with ordinary knowledge in the particular field can understand and practice the invention. No part of the device or method must be left to the reader's imagination. *All of the necessary steps and elements must be fully disclosed and described.* This does not mean that all technical terms or commonly known scientific principles must be set forth. However, since an insufficient disclosure will render a patent defective and inasmuch as the Patent Office is unwavering in its rule that no new matter may be added to an application, the importance of a complete disclosure cannot be overemphasized.

The application concludes with one or more claims. A claim may be considered a short summary of the invention and constitutes the most important part of the application. This is because it is the claims that determine the scope of the patentee's protection and the measure of his grant. If a claim contains specific limitations it is said to be of narrow scope and hence the protection it affords is limited. The more desirable claim will recite the invention in broad terms avoiding specific limitations.

Consider, for example, a patent application on a simple vacuum diode. A set of claims might read as follows:

1. A device comprising a base, an envelope secured to the base, the atmosphere within the envelope being a substantial vacuum, and a pair of electrodes located within the envelope.

2. A device comprising a base, an envelope secured to the base, the atmosphere within the envelope being a substantial vacuum, an electron emitting electrode and an electron collecting electrode each located within the envelope.

3. A device comprising a cylindrical base, a transparent glass envelope secured to the base, the atmosphere within the envelope being a substantial vacuum, an electron emitting electrode and an electron collecting electrode each located within the envelope.

Claim 1 is the broadest of the three claims since it is not limited as to the type of envelope nor to specific electrodes. It would be difficult if not impossible for a competitor to construct a vacuum diode without coming within the scope of this claim and therefore liable for infringe-

ment. Claim 3, on the other hand, could readily be avoided by a competitor for it calls for a cylindrical base and also for a transparent glass envelope. If the competing device does not meet every limitation of the claim or contain a full equivalent therefor, it does not infringe. Therefore, a vacuum diode with a square base or a nontransparent glass envelope would not infringe claim 3.

The patent applicant would therefore endeavor to obtain claim 1 in the processing of his application. However, let us suppose that at the time of filing the application the two-filament incandescent lamp was known and described in a patent or printed publication. A reading of claim 1 shows that each element as therein set forth is found in the lamp. The claim is said to be readable on the lamp and will be rejected by the Patent Office as having been anticipated by another. Claims 2 and 3, however, are not readable on a two-element incandescent lamp since each calls for "an electron emitting electrode and an electron collecting electrode." Therefore, the patent may be granted containing claims 2 and 3 but not claim 1.

It is seen then that if an invention is claimed too broadly, the claim will be rejected, or if inadvertently allowed by the Patent Office it will be invalidated by subsequent litigation. On the other hand, an unduly specific claim can be avoided by others and therefore is of little value to the patent owner.

During the pendency of the application, it sometimes occurs that another application discloses and claims substantially the same invention. The Patent Office must then determine priority of invention between the two inventors. The proceeding is called an interference and each applicant is called upon to submit evidence of priority. The most persuasive evidence is the inventor's notebook, written reports and photographs, providing each is suitably dated, signed and witnessed. The inventor endeavors to show that he not only was the first to conceive the invention but also that he exercised due diligence in reducing it to practice. If the laboratory notebook is carefully kept, it will give a complete picture of the day-to-day development of the invention. The notebook and other documentary evidence should be witnessed by someone, other than the inventors, who understands the written notes. The phrase "witnessed and understood" appearing over the dated signature of the witness on each page of the lab book can be most helpful to the inventor involved in an interference.

Rights of the Patentee

While the patent application is pending and being processed the inventor has no enforceable patent rights. *The terms "patent pending" and "patent applied for" on an article have no legal significance.* They merely put the public on notice that a patent may be issued in the future. There can be no infringement and hence no liability before the patent is actually granted.

From the day the patent issues, the patent owner has the right to exclude all others from making, using or selling the invention in the United States. It should be particularly noted that these rights are merely exclusionary. The grant of the patent does not in itself give the patentee the right to make, use or sell his own invention—his patent rights are limited to excluding others. If the invention is an improvement on another patented device, the improvement patentee would infringe the more basic patent were he to practice his own invention.

This may be readily seen by referring again to the hypothetical case of the patented diode. Assume that during the 17-year term of this patent another inventor obtains a patent on the improvement of adding a control grid. If the triode inventor were to manufacture his invention he would be infringing the claims of the diode patent. The diode inventor, likewise, could not legally make the patented triode. This produces a situation where each party is prevented from manufacturing the triode.

The practical solution is for one patentee to license the other or for the two parties to grant cross licenses on suitable terms so that each may make use of the others invention. It is this type of situation which

forms the basis for many cross-licensing arrangements between competing manufacturing concerns. Of course, upon the expiration of the diode patent, all rights therein pass into the public domain and hence the patentee of the triode improvement is free to practice his invention and the rest of the public is free to make diodes. And so the public eventually receives its reward for the exclusive right granted for a limited period to the diode inventor.

Conclusion

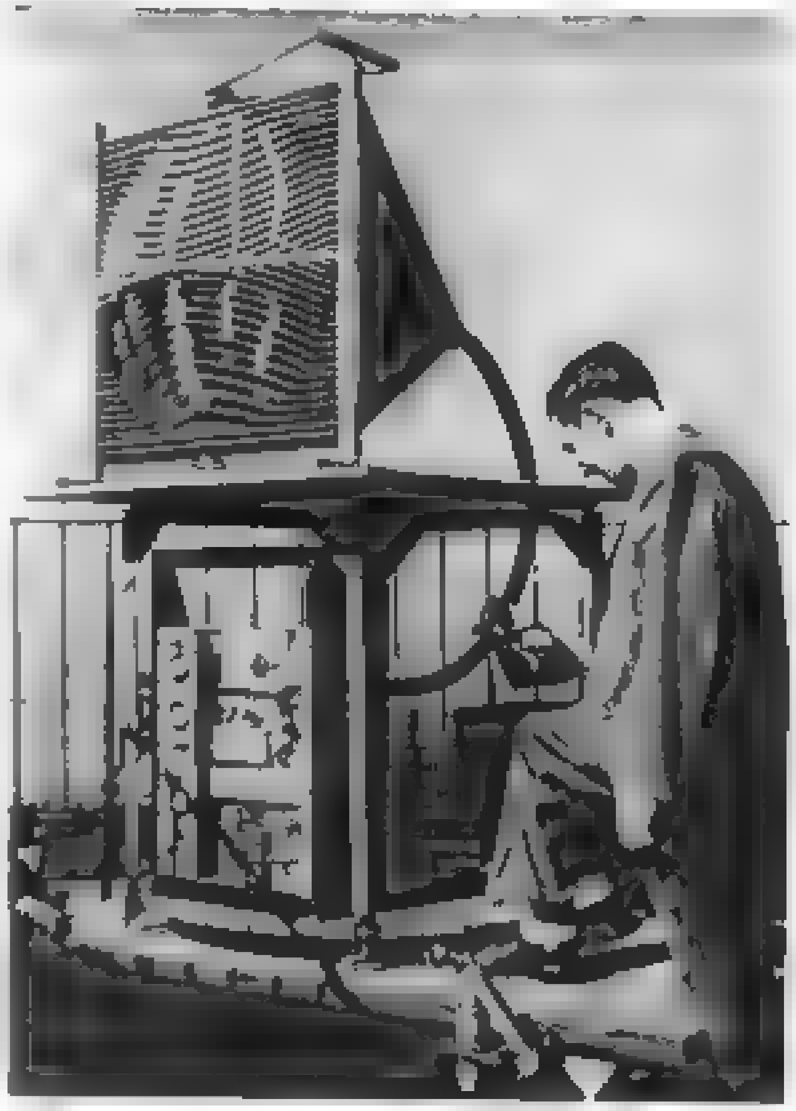
The ways in which the principles set forth in the foregoing are administered by Western Union's Patent Department were described by Mr. M. J. Reynolds, Assistant General Attorney in Charge of Patents, in the paper: "The Role of Patents in Western Union's Technical Developments," appearing in TECHNICAL REVIEW of January 1951, Volume 5, pages 17-21. The equities residing in patents are of considerable moment to a utility company such as the Telegraph Company, and retention of attorneys to protect the interests both of its inventor-employees and the assignee is fully justified. The patent attorneys' work is greatly facilitated when inventors understand the fundamentals of patents presented in this article.

Edward R. Hyde joined Western Union as an attorney (patents) in 1952 after having served three years as an Examiner in the United States Patent Office. He was graduated from Purdue University in 1948 with a B.S. in Electrical Engineering, and from George Washington University in 1951 with an LL.B. degree. Mr. Hyde is a member of the New York bar, District of Columbia bar, and the New York Patent Law Association.

C. B. YOUNG, Jr., Assistant to Radio-Wire Transmission Engineer

Path-Length Microwave Lenses

SINCE high-frequency radio energy and light are very much alike except for the difference in wavelength, many optical devices and techniques may be applied to microwaves.[1] For example, parabolic-shaped reflectors like those found in searchlights are widely used to obtain a narrow beam of microwave energy. Similarly, by the use of lenses, radio waves can be concentrated at a point, just as light can be focused into a bright spot. It should, of course, be recognized that these devices also work in reverse; for example, a lens will produce a narrow beam of energy from a small source placed at its "focus" or "focal point." Because of these characteristics, lenses are very useful as antennas in point-to-point microwave communication systems.



Lens with large horn-shield mounted on rotating platform for beam pattern tests

The use of glass and plastic lenses to focus microwaves has been very limited because of two practical disadvantages. The first of these is that materials which quite readily pass light may absorb a large portion of the energy at other frequencies. Secondly, since the efficiency of focusing is determined by the size of the lens relative to the wavelength of the energy, lenses several feet in diameter weighing several hundred pounds would be required.[2]

To avoid these difficulties, "artificial dielectrics" have been developed. The action of the molecules of glass in conventional lenses has been simulated by thin metallic rods, discs, and strips supported by a light-weight foamed plastic which is transparent to the radio waves (although not transparent to light). Lenses made in this fashion absorb very little of the microwave energy, and weigh much less than glass lenses, but may require several thousand metallic elements.[3-5]

Lenses achieve their focusing effect because of the difference in the velocity of the wave in the lens material and in air. The velocity of propagation through the lenses described above is less than the velocity in air; and the lenses are made thicker in the center than at the edges, so that the center part of an incident wave will be delayed relative to the outer part. A wave passing between two properly-spaced metal plates set parallel to the electric field appears to travel faster than in air. Lenses can be made from arrays of such plates; and, if thicker at the edges than in the center, they will have a focusing effect similar to the lenses above. The ratio of the velocity of propagation between the plates to the velocity in air determines the "index of refraction" of the lens, but this ratio depends on the spacing between the plates and the wavelength of the energy. Consequently the proper plate spacing must be accurately maintained, the sharpness of focusing varies with frequency, and the usable bandwidth is somewhat limited.[6]

Slant-Plate Lens

A wave passing between parallel conducting plates which are perpendicular to the electric field will travel with essentially the same velocity as in air. The plates will then have little effect on the progress of the wave unless they are bent or tilted in some manner that causes the direction of propagation to be changed. Several lens designs have been based on these ideas.[7-10] Figures 1 and 2 show how simple a lens of this type may be.[7] Energy radiated toward the lens by a directive source at the focal point, O, will spread out radially until intercepted by the parallel metal plates forming the lens. Then the actual distance traveled through the lens to the straight-through distance, 1/cosine θ_0. For the lens to focus properly it must convert a spherical wave (from the focal point) into a plane wave at the plane face EBD; that is, energy which leaves point O at a particular instant spreading out in different directions must later arrive at the plane EBD at the same time. Since the actual velocity is constant, this simply requires that the lengths of the different paths which segments of the wave may follow must be equal; therefore, the name path-length lens is applied. In Figure 1 the paths OE, OAB, OCD, and any other such paths must all be equal.

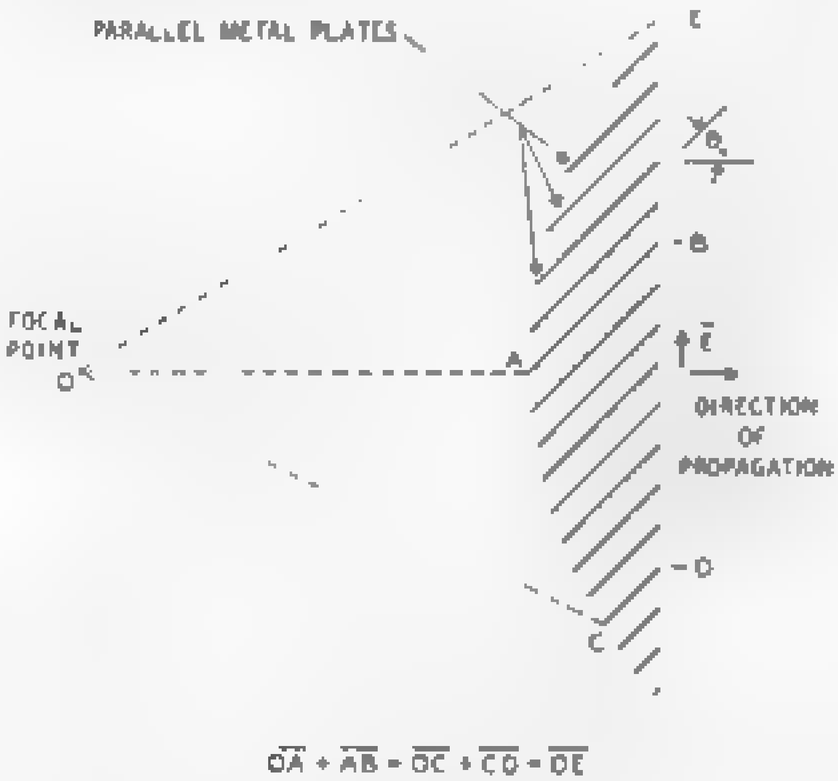


Figure 1. Side view of slant plate path-length lens

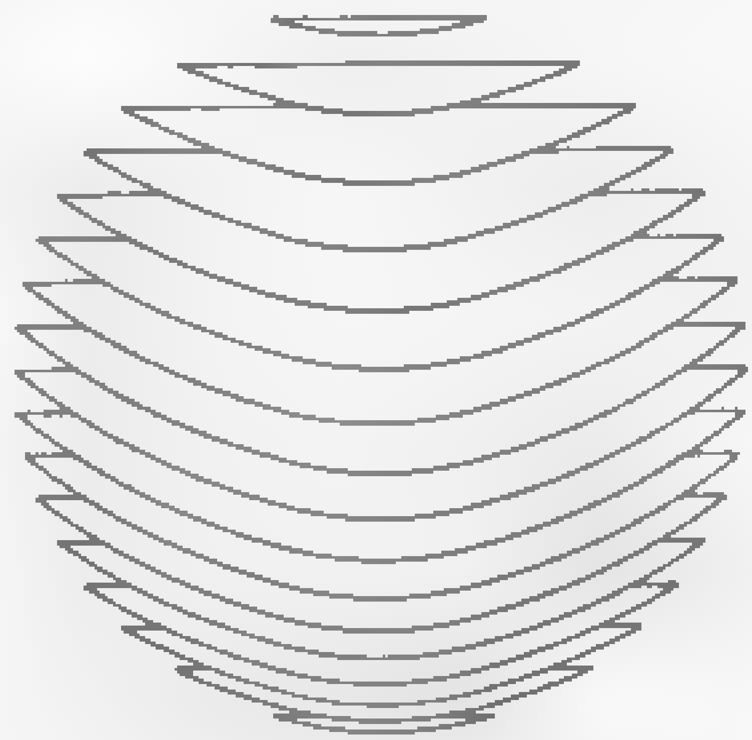


Figure 2. Rear view of slant plate path-length lens

the wave will be broken into small segments which are forced to follow the paths between the plates. These trapped waves will continue to advance with the same velocity they had in the air (if the plates are properly oriented with respect to the electric field, $\overline{E}$), but they must travel a longer path in order to reach the plane EBD at the face of the lens. It takes longer, therefore, for the energy to get through the lens, just as though it had been traveling straight through with a velocity less than in air. The index of refraction, the ratio of the velocity in air (which is also the actual velocity in the lens) to the straight-through component of velocity in the lens, is equal to the ratio of

Figure 2 shows how the edges of the plates must be cut in a hyperbolic curve to maintain this path-length equality over the entire structure.

It can be seen that the index of refraction and the focusing of the lens do not vary with frequency but depend only on the tilt of the plates. The only basic restrictions are that the plates must be thin, the spacing between the plates must be less than half the wavelength, and the transverse length of the plates (the horizontal length in Figure 2) must be long compared with the wavelength. These easily met requirements predict good performance over an extremely wide frequency range.

A Symmetrical Path-Length Lens

The first requirement of a beam-forming device such as a lens is that it must convert a spherical-shaped wave radiated from the focus into a plane wave on the opposite side of the lens. This plane wave will then propagate outward from the lens, as indicated in Figure 1, spreading slightly to form the beam. The beam is shaped not like a cylinder but like a cone; that is, most of the energy is confined within a small angular range. Furthermore, this main beam is surrounded by many weaker beams called sidelobes. Their amplitudes depend to a great extent on the distribution of energy over the radiating face of the lens. Consideration of the slant plate lens shows that if the energy incident on the curved face is symmetrical about the center, one-half of this energy will be confined to approximately one-third of the plane face. This results in relatively strong sidelobes directed at angles above the center line of Figure 1, that is, in one-half of the "electric plane." This is undesirable because these sidelobes contain energy which is wasted and, when the lens is positioned so that these lobes lie in the horizontal plane, they increase the possibility of interference between different systems.

Consideration of other possible designs which might yield low sidelobes in both the electric and magnetic planes and yet retain the advantages of simplicity and broadband performance predicted by the path-length approach led to the symmetrical configuration shown in Figures 3 and 4. This double convex lens is made of metal plates which are parallel along the flat portions but are bent in the middle. The lower half of the lens is the mirror image, instead of a continuation, of the upper half. The front and rear contours are made alike, or at least similar, so that energy captured by the plates at one face is released at a closely corresponding point at the opposite face. If the incident energy is symmetrical about the center of the lens, it is distributed symmetrically over the radiating face after being delayed by the extra path length between the plates. As with the slant plate lens, the lengths of all paths from the focal point through the lens to a plane perpendicular to the lens axis (the direction of the main beam) must be equal.

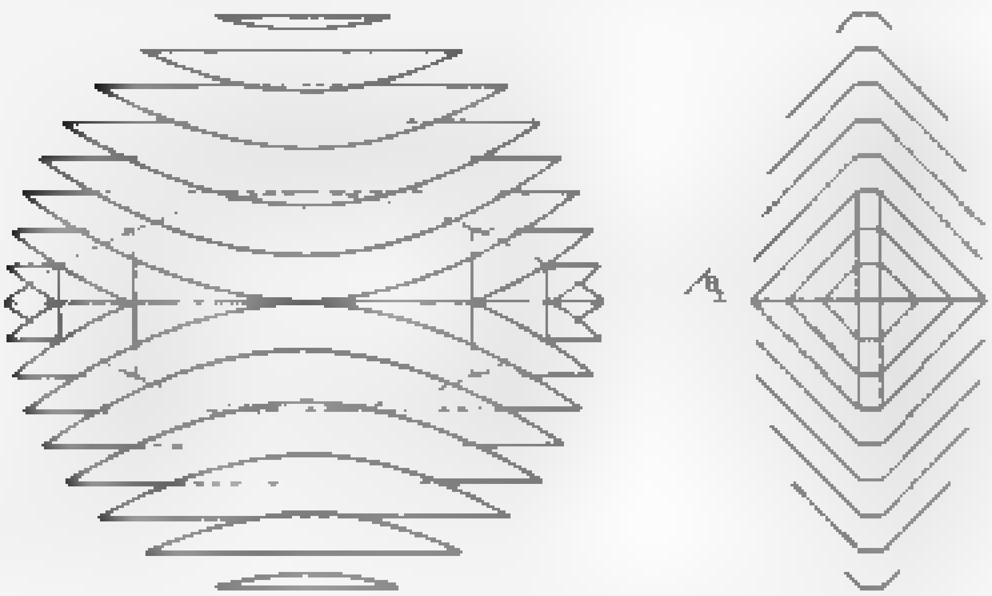


Figure 3. Rear and side views of a symmetrical path-length lens

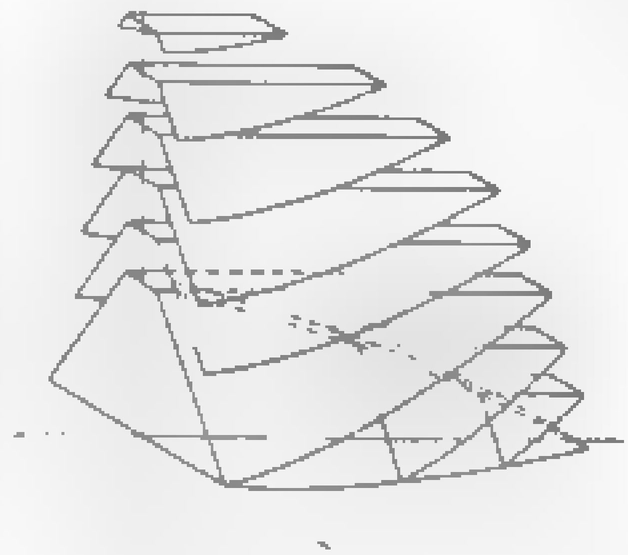


Figure 4. Perspective view of a symmetrical path-length lens

The bend in the middle of the plates can take any of several forms. The one shown is easy to make with readily available equipment.

In the center part of the lens the plates meet a "core" which is shaped somewhat like a football. Without this the upper and lower plates near the center would intersect as shown and then continue through the "inside" of the lens, forming a straight edge along which there would be insufficient delay of the wave. This core has a curved surface which makes the length of all paths through this section equal to the length of all other paths through the lens.

Experimental Results

In order to determine whether this structure would perform as predicted above, a model was constructed. The tilt angle of the plates, θ_0, was 42 degrees, making the effective index of refraction about 1.35. The focal length and diameter were made equal (30 inches), corresponding to an "f-number" of 1.0 in camera lenses. The plates, which must be good conductors and thin enough that the edges do not represent an appreciable obstruction to the wave, were made from 0.031-inch aluminum sheets. This structure is shown in Figure 5. The white blocks seen between the plates are spacers made of a foamed plastic which has negligible effect on the wave. The straight section forming the center of the bend was extended laterally, with small lips on the front and rear edges, to provide support for the plates as shown in the photograph.

This lens was "illuminated" by energy from a small horn positioned so that the wave incident on the lens appeared to come from the lens focal point. Measurements of the intensity of the wave on the opposite side of the lens showed reasonably smooth, symmetrical variations comparable to those on the horn side of the lens. Phase measurements (i.e., the difference between the actual wave and a true plane wave) over the output side of the lens showed only small errors. Some of these were eliminated by moving the feed-horn three inches farther away from the lens. The remaining errors over most of the lens face were less than about $\pm 1/32$ of a wavelength or ± 11 degrees in phase. Near the edges of the lens, however, the wave was not delayed enough; this caused errors of as much as an eighth of a wavelength. It is strongly suspected that these errors are caused by the small amount of overlap of the plates near the lens edges. From the photograph (Figure 5) it appears illogical to assume that the short plates at the top and bottom would properly guide the waves. This effect could probably be reduced by adding other plates in these sections, as there is no restriction on how close together the plates may be, nor any requirement that the spacing be the same

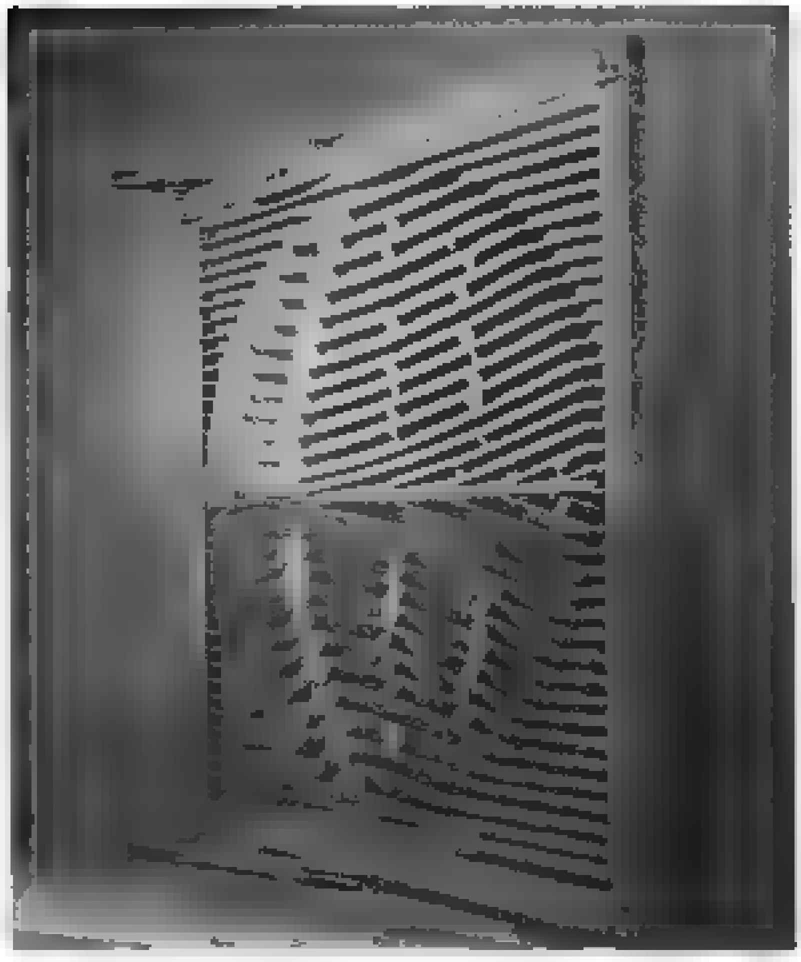


Figure 5. Experimental model of the lens of Figure 3

between all plates. Near the core in the center of the lens the phase variations were less than $\pm 1/16$ wavelength even though the mechanical tolerances on this hyperbolically-curved section were very poor

Although these results indicate that the lens focuses well, the only dependable measure of the focusing action of a lens is its "beam-pattern." The pattern in the electric plane (the plane perpendicular to the plates) is shown in Figure 6. The sidelobes are symmetrically low, and the narrow main lobe corresponds closely to that expected from a lens 10.6 wavelengths in diameter. The magnetic-plane pattern (Figure 7) is also quite satisfactory. It is believed that the wide-angle sidelobes shown as dotted curves are caused principally by two factors: radiation of the horn around the lens edges and the small phase errors over the lens face. The use of a complete horn-shield around the lens should eliminate the first source, and improved tolerances plus the addition of extra plates or masking near the lens edges should reduce the second source considerably. These patterns were measured with the horn positioned as above for minimum phase errors. Good patterns were also obtained with the source moved three inches closer to the lens (to the

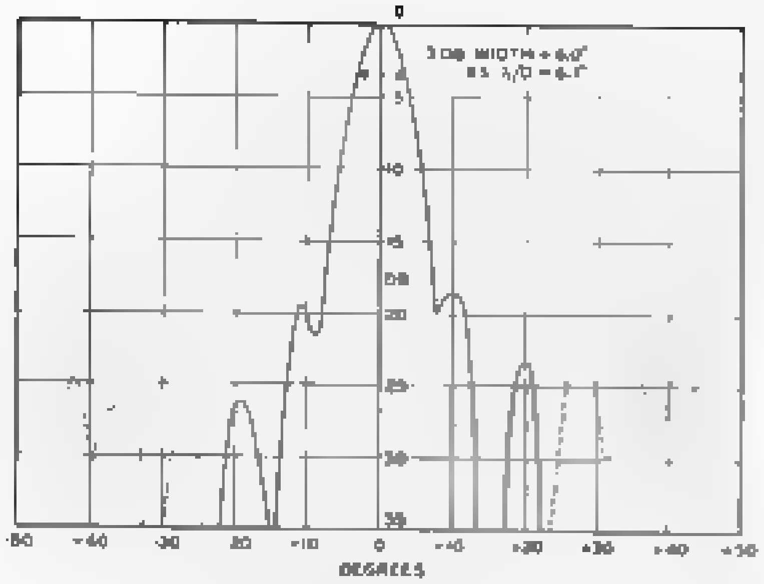


Figure 6. Electric-plane pattern of the lens of Figure 5 at 4185 mc

design focal point) and three inches farther from the lens. This demonstrates the relative insensitivity of lenses to defocusing.

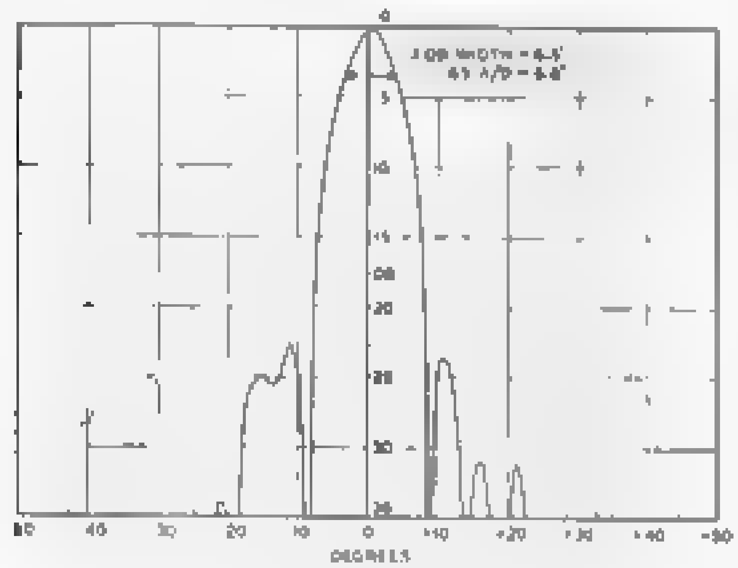


Figure 7 Magnetic-plane pattern of the lens of Figure 5 at 3890 mc

Higher-Order Effects

As is very often the case, the exact explanation of the factors involved is not as simple as that presented. A number of authors have suggested that the path-length theory omits consideration of effects which may be important, and one experimental investigation of the slant plate design[11] reported exceptionally poor results. The published theoretical analyses of parallel-plate media of this type[12-14] are rather limited and incomplete, in spite of the apparent advantages of path-length lenses.

For the type of structure considered above, the wave travels between the plates with essentially the same velocity as in air, but at each face of the lens there is a disturbance of the wave (somewhat like turbulence in water) which causes a change in phase not exactly accounted for by the path-length calculations. A study[15] of the available analyses indicates that the magnitude of the phase errors caused by this junction depends on several factors including the spacing between plates, the wavelength, the angle at which the wave strikes the plates, and the angle between the plates and a line drawn tangent to the lens "surface." The angles referred to vary over the lens faces, causing the phase change to vary.

Evaluation of these effects must await a more complete analysis, but certain general conclusions affecting the E-plane (side views, in Figures 1 and 3) are suggested by what has already been done. The first is that the tilt angle of the plates, θ_0, should be kept small, so that the angle at which the wave strikes the plates will be small. Secondly, the angle between the plates and the tangent to the lens surface should not decrease too rapidly near the lens edges. The only control of this, however, is by the choice of plate tilt angle, lens diameter and focal length, and the general shapes of the two surfaces of the lens. The spacing between the plates should be always somewhat less than half the wavelength and, perhaps, less than a quarter-wavelength near the edges where the above discussed angles are small.

Near the core section the relationships are quite complicated, and very little can be said about the theoretical aspects. The experimental results, however, indicate that the path-length method serves as a reasonably accurate approximation for the design of this part of the symmetrical lens described above.

Additional "turbulence" of the wave is introduced by the bend in the center of this lens, but an approximate analysis of this indicates that the phase errors caused are not appreciable. A bend which caused less abrupt changes in the direction the wave travels would be somewhat more desirable, however

Discussion

One of the principal advantages of lenses for use as microwave antennas is the absence of severe tolerances on warp,

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twist, lens thickness, or position of the feed. The allowable deformation of a lens greatly exceeds that of a parabolic-reflector antenna, for example. Path-length lenses have additional advantages over other lenses in their simplicity and even less critical construction. Neither the lengths of the plates nor the spacing between the plates forming the lens is especially critical. The tilt of the plates must be maintained rather accurately, however, since this determines the delay produced by the lens. This may be controlled by spacing blocks or ribs made of material which is transparent to microwaves.

The new path-length microwave lens described retains the principal advantages of earlier types without some of their inherent disadvantages. The primary improvement achieved by this new design is shown by the radiation patterns. Beam patterns with a sharp main lobe and symmetrically low sidelobes in both the electric- and magnetic-plane have been obtained. Other considerations should also be mentioned. In the slant plate lens, for example, the plates must be held at the proper angle with respect to the incident wave. In the symmetrical design this angle is much less important; the angle between the sloping sides of a plate is the one which must, and can more readily, be carefully controlled. Another factor in the use of the usual plano-convex lens is that any energy from a source at the focal point which passes through the lens and is reflected by the sudden change at the plane face becomes re-focused at the source. (Lenses are usually tilted to avoid this.) Energy reflected from either face of the double-convex lens diverges rapidly. Furthermore, reflections from the portion of this new lens which lies directly in front of the feed may be partially cancelled by offsetting the upper and lower halves of the lens (Figure 3) by one-fourth of a wavelength, so that the reflected wave from one half will travel round-trip a total of one-half wavelength farther than the reflection from the other half and their resultant effect will be zero. This technique could not be applied to the earlier type discussed above except by splitting the lens vertically (Figure 2).

The path-length theory of lens design has proved reasonably accurate for the cases investigated, but a more complete analysis is required in order to be able to account for the errors which may arise. Until this is available, the results predicted by the path-length approach may not always be achieved. A study of the factors involved indicates certain general guides to be followed, but even these do not insure that optimum results will be obtained unless the resulting errors are minimized experimentally.

Acknowledgment

The writer wishes to acknowledge his indebtedness to all those at Western Union who assisted in this project. Particular mention should be made of R. E. Greenquist and A. J. Orlando for their many stimulating comments and helpful discussions. The writer is also grateful for the guidance of Dr. Nathan Marcuvitz of the Polytechnic Institute of Brooklyn in the study of the theory.

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Telecommunications Literature

HANDBOOK OF MICROWAVE MEASUREMENTS — MOE WIND and HAROLD RAPAPORT, Editors — Brooklyn Polytechnic Institute, N. Y., 1954. 960 pp., $12.00. The rapid growth of the microwave field in recent years has brought about the development of many different techniques for measuring the characteristic quantities but has made it difficult for engineering and technical personnel to be conversant with all the diverse methods available. This book compiles the work of 25 specialists writing about 20 major quantities of interest. The introduction starts with a water-wave analogy to electromagnetic waves which leads to a readily understandable development of most of the fundamental concepts and equations required for a practical approach to microwave measurements. This includes discussions of wave propagation, modes, standing waves, the concept of wave impedance, propagation constant, cutoff frequency, and waveguide wavelength. Each section of the book covers in detail the measurement of a particular characteristic quantity. In general each of these begins with a discussion of theoretical aspects followed by descriptions of several applicable methods. Step-by-step procedures and illustrative examples are given covering many cases. Very valuable sections are included pointing out precautions, sources of errors, and accuracy of measurement. Most chapters conclude with a long list of references to further information. In addition to covering the more common microwave measurements of frequency, standing wave ratio, attenuation, power, Q, impedance, noise figure and antenna characteristics, the Handbook describes methods of measurement of dielectric constant, attenuation constant, phase constant, spectrum analysis, RF leakage, and characteristics of crystals, receivers, and tubes.Four appendices discuss the use of transmission line charts, impedance diagrams, Rieke diagrams, and impedance matching techniques. The thoroughness of presentation makes this a valuable guide and reference for those working in the microwave field. The simplicity of style and organization of the material make it suitable for those who want only a general understanding. This Handbook could also serve well as the text for an excellent course in microwave measurements.— C. B. YOUNG, JR., Ass't to Radio-Wire Transmission Engineer.

TELEVISION AND RADIO REPAIRING — JOHN MARKUS — McGraw Hill Book Company, Inc., N. Y., 1953. 556 pp., $7.95. The hobbyist will find information in this book which he can immediately use to fix ordinary troubles in radio and TV sets. An experienced electronic technician will learn new ideas for short cuts in testing without expensive instruments. The younger technicians have here the accumu-

lated experiences of two decades or more of the old timers in radio servicing. Among the 22 chapters, completely devoid of mathematical formulas, are suggestions on tools needed, how to use multimeters and tube testers, with comparisons of the merits of various type instruments; how to solder; and replacement of components including phono pickups and needles. Practical information on resistor and capacitor troubles is included with simple test methods. Charts in the text clarify the differences in color coding systems in use from 1938. The book is well illustrated with how-to-do-it pictures. — F. W. MARTIN, Wire and Repeater Technician, Richmond, Va.

TELEPHONY, VOLUMES I AND II—J. ATKINSON—Sir Isaac Pitman & Sons, Ltd., London. Vol. I 1955, 512 pp; Vol. II 1952, 873 pp., $13.30. These volumes represent the up-to-date edition of an earlier published work giving a detailed exposition of the Telephone Exchange System, Manual and Automatic, of the British Post Office. Volume I covers the principles and circuit elements found in telephone switching together with the principles involved in the design of a manual telephone switching system. Volume II deals with the theory and practice of automatic switching. The principles of the Step-by-Step, Non-Director, Director, Automatic and Manual Intercommunication, Marker Control Uniselector, Power Drive, Relay and Crossbar Systems are adequately described. The material presented in these volumes is easily read because of the clear type, and the large page size permits the use of larger circuit diagrams. The books are a good acquisition for a Telecommunication Library and as a reference source for those developing and designing telephone switching systems and closely related fields of circuitry. — J. J. MC MANUS, Engineer, Systems and Equipment.

PLASTICS ENGINEERING HANDBOOK — The Society of the Plastics Industry, Inc.—Reinhold Publishing Corp., N. Y., 1955. 852 pp., $15.00. The second edition of the Plastics Engineering Handbook of The Society of the Plastics Industry is a valuable reference guide for the materials supplier, designer, molder, fabricator, finisher and user of plastics. The handbook is divided into five major sections: Materials and Processing, Design, Finishing and Assembly, Testing and SPI Standards. Each of the chapters of the book was written by a committee of engineers now actively engaged in the plastics field. As a consequence the volume contains a complete summarization of the present knowledge of plastic engineering. The handbook contains physical, chemical and electrical data for various plastic materials. Of special note is the chapter on cementing, welding and assembly which covers the basic methods of joining plastics to themselves and to other materials.—E. B. GEBERT, Metallurgist, Physical and Chemical Research.

ARITHMETIC OPERATIONS IN DIGITAL COMPUTERS—R. K. RICHARDS—D. Van Nostrand Co., Inc., N. Y., 1955. 397 pp., $7.50. This book, written by R. K. Richards, Development Engineer of International Business Machines Corp., is recommended for those who desire a knowledge of the internal operations of digital computers without the necessity of studying complicated circuit diagrams and circuit descriptions. The book begins with a discussion of the system of symbols used to represent quantities, and an explanation of Boolean algebra applied to computer operations and switching networks. The adding, subtracting, multiplying and dividing arithmetic operations that take place within digital computers are described in considerable detail for both decimal and binary systems of numbers. The book does not treat with the detail circuitry or mechanical aspects of computers. Instead, the means for performing arithmetic operations are explained through the use of "functional block diagrams" where it is understood that any set of physical components which provide the indicated functions may be used. The text is not written in terms of any one particular type of computer. For example, the principles of programming are described in general terms by using a simplified "specimen" machine as a model. While this method does not permit one to become an expert on any one type of computer, it does give a general knowledge of fundamentals that are applicable to all types of digital computers—W. B. BLANTON, Automation Engineer.

TRANSISTOR AUDIO AMPLIFIERS—RICHARD F. SHEA—John Wiley and Sons, Inc., N. Y., 1955. 219 pp., $6.50. The practical engineer with a broad background in vacuum tube circuits will find that this book will help him to overcome his natural trepidation at entering the new transistor field. The book is well organized. The table of symbols used throughout the text is particularly useful. Although the treatment employs a minimum of higher mathematics, a reader, so inclined, may utilize the many excellent references contained in the Bibliography. Some basic net-

work theory and an explanation of the three most common ways of representing the voltage and current relations in transistor circuits are included as a preliminary to the more specific design material. One section contains technical data on many types of transistors. In the amplifier design section the author discusses basic amplifier design, coupled stages, preamplifiers, Class A and Class B power amplifiers and examples of practical amplifier design. This book is a worthy successor to "Principles of Transistor Circuits" by the same author.—A. E. MICHON, Project Engineer, Radio-Wire Transmission.

Patents Recently Issued to Western Union

High-Speed Facsimile Transmitter

L. G. POLLARD

2,695,925—NOVEMBER 30, 1954

A facsimile transmitter designed for 1800-rpm drum speed employs a transparent drum inside which the message blank rolled up with the intelligence facing outwardly is held in place by centrifugal force. A hinged gate at the outer end of the drum opens for admission of the message and also mounts an outer bearing with means for gripping the end of the drum, all designed for high-speed operation. The scanning lamp and photocell travel on an outside carriage parallel to the drum. For generating control signals a light beam from a lamp inside the drum passes through a gap in the rolled message to an outside photocell as the drum revolves.

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Facsimile Receiving Apparatus

C. R. DEIBERT, F. T. TURNER, R. H. SNIDER

2,700,701—JANUARY 25, 1955

Rapid phasing means suitable for a recorder operating at 1800 rpm. Normally the transmitter sends a stand-by tone to line which upon insertion of a message blank is switched to a phasing tone of different frequency and interrupted at a 30-cycle rate, for a period of 2.5 seconds only. Receipt of the phasing tone causes rotation of a rotary transformer in circuit with the receiver drum motor power supply to increase the supply frequency by one cycle and the drum motor speed to 1830 cycles, the drum at the same time producing a local phasing pulse for each revolution. Within the 2.5-second period, the pulses from the accelerated motor will reach coincidence with the incoming pulses and normal speed transmission and recording ensues automatically. At end of message a very short pulse of the stand-by tone follows to initiate rapid feed-out and shear operation at the recorder and then the steady stand-by tone. If, however, a new message is ready, the end-of-message pulse is succeeded instead by the interrupted phasing tone and phasing proceeds simultaneously with the foregoing operations. Other features peculiar to continuous high-speed operation, as well as provision for variable length messages and start-up on nonsynchronous power are included.

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Telegraph Signal Bias and Distortion Meter

W. D. CANNON

2,715,157—AUGUST 9, 1955

An instrument for measuring bias in telegraph signals by accumulating a condenser charge representative of the average length of single unit spacing intervals and comparing this with a reference potential. This avoids the effect of the length variations often encountered in the marking stop pulse of start-stop signals. To accommodate nonsymmetrical signals, the bias of the input relay is altered automatically between M-S and S-M transitions. To indicate percent distortion, the length of the shortest spacing signal is similarly measured.

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Electric Motor Speed Regulation

F. T. TURNER, L. G. POLLARD, C. R. DEIBERT

2,715,202—AUGUST 9, 1955

Method for stabilizing the rotation of an a-c motor such as is used for high-speed facsimile which in the example illustrated is controlled from a frequency standard which produces 60 cycles for driving the motor and 1440 cycles for phase comparison. A capacity tone generator on the motor shaft also produces 1440 cycles which is matched against the standard in a phase detector to produce an error signal and this in turn by its magnitude and polarity controls the phase and magnitude of the 60-cycle motor driving voltage.

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